Argonne National Laboratory

INSTITUTIONAL PLAN

FY 2001 – FY 2006

Operated by the University of Chicago for the
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October 2000

This October 2000 *Institutional Plan* was originally prepared in the early spring of 2000. It generally describes the activities and plans of Argonne National Laboratory as of that time. Thus, for example, financial data for FY 2000 are mid-year projections. In addition, a few selected revisions to the *Draft Institutional Plan* of May 2000 are included to reflect comments received and major shifts in plans.

Argonne National Laboratory, with facilities in the states of Illinois and Idaho, is owned by the United States Government and operated by the University of Chicago under the provisions of a contract with the Department of Energy.

Contents

I. Laboratory Director's Statement

This *Institutional Plan* describes what Argonne management regards as the optimal future development of Laboratory activities. The document outlines the development of both research programs and support operations in the context of the nation's R&D priorities, the missions of the Department of Energy (DOE) and Argonne, and expected resource constraints. The *Draft Institutional Plan* is the product of many discussions between DOE and Argonne program managers, and it also reflects programmatic priorities developed during Argonne's summer strategic planning process. That process serves additionally to identify new areas of strategic value to DOE and Argonne, to which Laboratory Directed Research and Development funds may be applied. The *Draft Plan* is provided to the Department before Argonne's On-Site Review. Issuance of the final *Institutional Plan* in the fall, after further comment and discussion, marks the culmination of the Laboratory's annual planning cycle.

Plan Structure

Chapter II of this *Institutional Plan* describes Argonne's missions and roles within the DOE laboratory system, its underlying core competencies in science and technology, and six broad planning objectives whose achievement is considered critical to the future of the Laboratory. Chapter III presents the Laboratory's "Science and Technology Strategic Plan," which summarizes key features of the external environment, presents Argonne's vision, and describes how Argonne's strategic goals and objectives support DOE's four business lines. The balance of Chapter III comprises strategic plans for 23 areas of science and technology at Argonne, grouped according to the four DOE business lines. The Laboratory's 14 major initiatives, presented in Chapter IV, propose important advances in key areas of fundamental science and technology development.

The "Operations and Infrastructure Strategic Plan" in Chapter V includes strategic plans for human resources; environmental protection, safety, and health; site and facilities; security, export control, and counterintelligence; information management; communications, outreach, and community affairs; performance-based management; and productivity improvement and overhead cost reduction. Finally, Chapter VI provides resource projections that are a reasonable baseline for planning the Laboratory's future.

Recent Research Accomplishments

I am pleased to report that Argonne made significant advances in all of its major program areas over the past year.

As described in Chapter IV of this *Institutional Plan*, Argonne is proposing construction of the Rare Isotope Accelerator (RIA), an unparalleled nuclear physics facility for exploring the properties of atomic nuclei near the limits of their stability and the fundamental roles these nuclei play in the processes of the universe. The Laboratory's basic concept for this national user facility — which exploits the superconducting technology for ion acceleration that we pioneered — is the design basis for a DOE request for approximately $500 million to support construction. Over the past year we made major advances toward the innovative technologies to be used. We analyzed in detail the concept of simultaneously accelerating several different charge states of heavy ions through a powerful superconducting linear accelerator, which will allow delivery of uranium beams at over 100 kilowatts to RIA production targets. Seminal measurements confirmed the viability of the new fast gas catcher concept for chemically independent production of intense beams of rare isotopes across the entire periodic table. In addition, multidisciplinary coordination among nuclear physicists and researchers from several engineering disciplines produced preliminary designs for RIA targets capable of operating at power densities above one megawatt per cubic centimeter. This vital new research facility would be well served indeed by Argonne's central location, its proximity to major universities, and, most of all, its outstanding scientific and technical staff. (See Section IV.A.1.)

Proteins and similar macromolecules are the "elementary particles" of living organisms, and understanding their structure and function is critical to advancing biological science and biotechnology. Argonne's Structural Biology Center (SBC) is using the powerful X-rays of the Advanced Photon Source (APS) and a unique charge-coupled device detector to make the following major contributions to deepening that understanding:

- Collection of multiwavelength anomalous dispersion (MAD) data much faster than ever before possible — 23 minutes for the structure of a 16-kilodalton protein at a resolution of 2.25 angstroms.
- Determination of the structure of an enzyme to the highest resolution of any large protein to date — 0.66 angstroms for the structure of human aldolase reductase.
- Exploration of the unique capabilities of the APS and SBC beamlines to collect data critical to determining the high-resolution structures of very large, complex ribosomal assemblies — the 50S and 30S ribosomal subunits.

As an essential complement to these activities, we have implemented robotic strategies as the foundation of automated systems for cloning and expressing proteins on a very large scale never before undertaken in the public sector. In just six months, during development of robotics methods, we cloned 150 genes that had not been expressed previously. This work in support of the U.S. Genomics Initiative deserves to be substantially expanded into a large multirobotic laboratory supporting several modes of high-throughput research in molecular biology. (See the major initiative High-Throughput Systems for Biomolecular Research in Section IV.A.2.)

At the APS, researchers used radiation from an undulator beamline and nuclear resonant inelastic scattering to determine the phonon density of states in iron under pressures up to 153 gigapascals. Such pressures are equivalent to those found at Earth's core, where iron-rich alloys are prevalent. Information about the structure and composition of materials at the cores of Earth and other rocky planets is fundamentally important to earth scientists and geophysicists. More generally, the new research proves long-held theories about thermodynamic, energetic, and elastic parameters for iron at extremely high pressures, and it opens doors to a diverse array of basic and applied investigations in areas including seismologic interpretation, planetary science, and even the development of valuable new thin-film materials, such as data storage media.

In late 1999, experimenters at the low-energy undulator test line (LEUTL) facility at the APS found evidence for self-amplified spontaneous emission (SASE) at 530 nanometers in a linear-accelerator-driven free-electron-laser (FEL) configuration. At the time, this wavelength was the shortest at which SASE had been observed in such a configuration. The LEUTL project is helping to pave the way to fourth-generation X-ray sources based on FELs, which will produce X-ray intensities nine to ten orders of magnitude greater than those of third-generation sources such as the APS and will open revolutionary new areas of investigation. (See the major initiative Fourth-Generation X-ray Source in Section IV.A.6.)

In a remarkably rapid development effort, researchers from Argonne and the Engelhardt Institute of Molecular Biology in Moscow recently created biological microchips (biochips) that can quickly identify 7 mutations that confer on the tuberculosis bacterium resistance to various antibiotics. Further development aims at detecting a total of 30 mutations. This new technology promises to become a vital tool in combating the worldwide resurgence in tuberculosis caused by bacterial strains that are resistant to multiple drugs. By identifying in a matter of minutes the particular strain afflicting a patient, physicians will be able to quickly prescribe the best antibiotic treatment. Today, that diagnosis takes many weeks and is much more costly. (See the initiative Biochips and DNA in Section III.D.1.l.)

In March of this year, DaimlerChrysler completed conversion of the laser weld monitoring systems at its state-of-the-art Indiana Transmission Plant to a new technology pioneered by Argonne researchers. The technology is being commercialized by Spawr Industries, which integrated it into a laser beam delivery system for better control of weld process variations. As a laser weld joining steel parts is made, an infrared monitor detects heat from directly above the weld and provides feedback on its integrity. The new technology is much less costly and time-consuming than earlier approaches, and it greatly reduces the need for destructive testing and the associated generation of scrap. Based on laser research at Argonne conducted in partnership with DaimlerChrysler, Ford, General Motors, and Delphi Energy and Engine Systems, this technology illustrates well the contributions being made by the Laboratory's Transportation Technology R&D Center. (See Section III.D.2.a.)

I am pleased to report that in April 2000 a review committee of the National Academy of Sciences strongly endorsed Argonne's electrometallurgical technology for treating spent nuclear fuel. The committee's final report recommended application of the technology to treating spent fuel from the Experimental Breeder Reactor-II (EBR-II) and other sodium-bonded metallic spent fuels, in preparation for disposal. The committee further recommended that the technology be considered seriously for other types of spent fuel. The committee's conclusions were supported by a major demonstration of the technology — undertaken by the Laboratory — that has successfully met all its goals. By the end of FY 1999 we had processed all 100 EBR-II driver fuel assemblies allowed by current environmental documentation. Processing of blanket assemblies continued into FY 2000, with 18 completed by April. After completion of an environmental impact statement, DOE can decide to proceed with electrometallurgical treatment of its remaining sodium-bonded spent fuel with confidence that technical questions about the process have been answered favorably. (See Section III.D.3.a.)

Argonne's broad expertise in nuclear technology is proving very valuable for DOE activities serving nonproliferation and international nuclear safety. For example, at the BN-350 fast breeder reactor in Kazakhstan, the Laboratory provides technical leadership for a collaboration of Kazakh organizations and U.S. partners that recently completed packaging for safe long-term storage all accumulated normal spent fuel; work on failed and experimental fuel has begun. Under a recent agreement between Kazakhstan and the United States, Argonne will provide technology for the permanent closure of the reactor and will help manage U.S. assistance in that work.

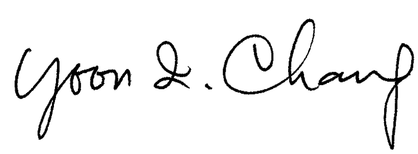
Interlaboratory Collaborations

Increasingly, the DOE laboratories are cooperating on R&D programs, much as divisions within a multiprogram laboratory work together to bring special capabilities to bear on a common R&D problem. The Appendix to this *Institutional Plan* describes Argonne's direct R&D collaborations with other laboratories.

The most important of Argonne's interlaboratory collaborations is the Spallation Neutron Source project, the largest scientific user facility under development by DOE. Sited on the campus of Oak Ridge National Laboratory, this project is supported by six national laboratories. Argonne is leading the development of neutron scattering instruments, with the extensive involvement of the neutron user community.

Support and Operations

Argonne assigns high priority to its support and operations functions, not only because they are critical to the successful accomplishment of the Laboratory's programmatic objectives, but because the quality of their performance can affect Argonne's workers and neighbors, DOE, and the nation. Prominent issues include (1) security and counterintelligence and (2) Integrated Safety Management. As indicated by this *Institutional Plan*, Argonne is working closely with the Department to address challenges in these areas.



Yoon I. Chang
Interim Laboratory Director

II. Missions, Roles, and Critical Objectives

Argonne National Laboratory is a large multi-program laboratory operated by the University of Chicago for the U.S. Department of Energy. The Laboratory's mission is basic research and technology development to meet national goals in scientific leadership, energy technology, environmental quality, and national security. To accomplish its mission for the Department and the nation, Argonne continually strives to advance the frontiers of science and to use its leading-edge capabilities in science and engineering to provide quality solutions for customers and stakeholders. In these efforts the Laboratory often works closely with other DOE laboratories so that the full capabilities of the DOE laboratory system are brought to bear on priority problems in science and technology.

A. Mission Areas

Argonne's major mission areas are the following:

- *Fundamental Science*

Experimental and theoretical work in the physical, biological, computing, and environmental sciences to support the development of energy and environmental technologies and to advance general scientific understanding. Major research thrusts include advanced techniques for X-ray and neutron science, algorithms and tools for massively parallel computers, studies of the human genome, biochip technologies, synthesis of advanced materials, detector systems for frontier experiments in particle physics, and studies of nuclear structure far from stability.

- *National Research Facilities*

Development and operation of national facilities for use by university, industry, and national laboratory groups in research on technology-related and basic-science problems; development of advanced instruments and methods for facilities-centered research. Major national user facilities currently operated by Argonne include the Advanced Photon Source, the Intense Pulsed Neutron Source, and the Argonne Tandem-Linac Accelerator System. The Advanced Photon Source, a $1 billion national investment completed in 1996, is the world's most brilliant source of X-rays for forefront research in technology and science; it has become one of the world's most widely used research facilities.

- *Energy Technologies*

Advanced nuclear technologies supporting civilian nuclear power; technologies for efficient energy utilization in the transportation and industrial sectors, for energy storage, and for fossil energy; supporting research in materials, chemical, and electrochemical technologies. The Laboratory's capabilities in these areas are focused on the safety and efficiency of light-water nuclear reactors; international nuclear safety; energy efficiency, through the programs Partnership for a New Generation of Vehicles and Industries of the Future; advanced batteries and fuel cells; high- and low-temperature superconducting materials and their applications; advanced fossil fuel conversion technology; and production of chemicals from agricultural and other biobased feedstocks.

- *Environmental Technologies*

Technologies for nuclear waste management, nuclear decontamination and decommissioning (D&D), industrial waste management, and site remediation and restoration. Focuses include conditioning DOE spent fuel for long-term disposal through use of electrometallurgical processing, D&D of obsolete light-water reactors, advanced site characterization techniques, and biological remediation technologies.

- *National Security*

Technologies for arms control, nonproliferation, and infrastructure assurance. Areas of emphasis are reduced-enrichment fuel for research reactors throughout the world, systems for materials control and accounting, and methodologies and tools for assuring the reliability and security of critical national infrastructures.

- *Technical Evaluation*

Characterization and evaluation of nationally important projects and technology options in terms of their environmental, cost, or other implications. Major activities in this area include assessments of environmental regulations and policies, site-specific environmental impact and remediation studies, and evaluations of advanced energy technologies.

Argonne contributes to U.S. science and mathematics education through programs for students and teachers. Participation in Laboratory programs by university faculty and students brings their talents to bear on significant research problems and contributes to the education of future scientists and engineers. An important purpose of these programs is to encourage members of underrepresented societal groups to enter careers in science and engineering.

Pervading all Argonne missions is the transfer of technology, particularly through R&D partnerships with industry and universities. These partnerships capitalize on the Laboratory's expertise and facilities. Principal mechanisms include cooperative R&D, use of major facilities, work for non-DOE sponsors, staff exchanges, and licenses.

An important Laboratory goal is excellence in protecting the environment and the health and safety of its workers and the public. In conducting all its missions, Argonne's policy is that these considerations receive the highest priority in the Laboratory's operations.

B. Roles in an Integrated DOE Laboratory System

In April 1995 DOE established the Laboratory Operations Board to guide the Department's management of its laboratory system. In July 1996 the Board published the *Strategic Laboratory Missions Plan — Phase 1* (URL: www.doe.gov/news/docs/summary.htm), which delineated the roles — "principal," "major contributing," or "specialized participating" — of each multiprogram laboratory in each of the four DOE major mission areas. Argonne's roles are as follows:

DOE Mission Area	Argonne Role
Fundamental Science	Principal
Energy Resources	Principal
Environmental Quality	Major Contributing
National Security	Specialized Participating

These role assignments recognize that DOE's multiprogram laboratories operate as part of an integrated system, within which the Department's programs can use the combination of capabilities at one or more laboratories that best meets their needs.

Cooperation among the DOE laboratories, particularly through direct R&D collaborations, is continuing to deepen. This trend toward a more integrated laboratory system is driven by ever improving communications technologies and by increasing experience and innovation with collaborative research at both DOE and the laboratories. A complementary trend is toward closer coordination of planning by DOE program offices, both among themselves and with other federal agencies. The expansion of R&D collaborations among DOE laboratories is sufficiently important that the Appendix of this *Institutional Plan* is devoted to describing it in more detail from an Argonne perspective. (See "Argonne in an Integrated DOE Laboratory System.")

Argonne in an Integrated DOE Laboratory System

See the Appendix for a description of Argonne's R&D collaborations with other DOE laboratories.

C. Core Competencies Based in Science and Technology

Through more than a half century of achievement in large-scale, multidisciplinary R&D,

Argonne has developed a broad set of scientific and technical capabilities and integrated them into distinctive core competencies that enable the Laboratory to perform its missions effectively for DOE and other sponsors.

The Laboratory articulates its core competencies and their underlying technical capabilities for at least three major reasons: (1) to facilitate its internal strategic planning, (2) to communicate the Laboratory's general nature and functions to outsiders, and (3) to help DOE and other potential sponsors understand how to employ the Laboratory most advantageously.

Argonne possesses the following core competencies:

- Integration of a broad science and engineering base into the development and evaluation of nuclear and other advanced energy technologies
- Design, construction, and operation of large accelerator-based user facilities and related technologies
- Conduct of large-scale basic and applied research programs in materials science, chemical sciences, biosciences, environmental science, physics, and mathematics and computer science
- Assessment, development, and testing of energy-efficient industrial, transportation, and other end-use technologies
- Application of modeling, simulation, and advanced computing and communications to studies of complex systems and phenomena
- Integration of environmental research, technology, development, and assessment to address complex environmental problems
- Planning and implementation of R&D partnerships with industry and universities to address problems in primary mission areas
- Education and training of future scientists and engineers by use of frontier research techniques and facilities

The scientific and technological capabilities underlying these eight core competencies are described in Table II.1.

D. Critical Objectives

Argonne regards a number of broad planning objectives as sufficiently important that their achievement constitutes a critical set for the Laboratory:

- Conduct science and technology programs that effectively support DOE missions and that are judged outstanding by the research community and by DOE program managers.
- Operate Argonne's major user facilities — the Advanced Photon Source, the Intense Pulsed Neutron Source, and the Argonne Tandem-Linac Accelerator System — in a way that maximizes research productivity and user satisfaction.
- In partnership with industry, successfully develop energy and environmental technologies — for transportation, advanced fossil energy conversion, nuclear waste treatment, and other applications — that meet industry and national objectives.
- Conduct the Laboratory's operations and support functions to provide, at the lowest possible cost, high-quality administrative and support services, along with an effective physical infrastructure.
- Aggressively implement Integrated Safety Management, making environmental protection, safety, and health fully a line management responsibility with unambiguous lines of authority; rank with the best in class among all research organizations in safety performance.
- Continuously improve the Laboratory's standing as a trusted neighbor and asset in the local community, Illinois, and the Midwest region.

These critical objectives are discussed in Chapter III ("Science and Technology Strategic Plan") and in Chapter V ("Operations and Infrastructure Strategic Plan") of this document.

Table II.1 Capabilities Underlying Argonne Core Competencies

SCIENCES

Materials Sciences
- Superconductivity
- Magnetic Materials
- Surface and Interface Studies
- Defects and Disordered Materials
- Neutron and X-ray Diffraction and Scattering
- Analytical and Transmission Electron Microscopy
- Thin-Film Materials
- Complex Oxides
- Materials Simulation and Theory

Chemical Sciences
- Theoretical and Computational Chemistry
- Experimental Chemical Dynamics and Kinetics
- Reactive Intermediates in the Condensed Phase: Radiation and Photochemistry
- Carbon Energy and Complex Materials
- Photosynthesis, Natural and Artificial
- Metal Cluster Chemistry
- Heavy-Element Coordination Chemistry and Separations Science
- Heavy-Element Photochemistry, Photophysics, and f-Element Interactions
- Atomic, Molecular, and Optical Physics
- Electrochemistry
- Fluid Catalysis
- Carbon Management, Biochemical and Geochemical

Biosciences
- Structural, Cellular, and Molecular Biology
- Genome Analysis
- Protein Engineering
- Computational Biology

Environmental Science
- Ecology
- Bioprocessing
- Environmental Molecular Science
- Atmospheric Sciences and Climate Change Modeling
- Inorganic and Isotopic Geochemistry

Synchrotron Radiation Techniques
- Biostructure Determination
- Time-Dependent Materials Characterization
- Micromachining
- Atomic Physics and Surface Science
- Advanced X-ray Optical and Detection Techniques
- Synchrotron Radiation Instruments and Techniques
- X-ray Imaging and Holography
- X-ray Free-Electron Laser

Mathematics and Computer Science
- Numerical Libraries and Programming Tools
- Computational Differentiation
- Parallel and Distributed Computing
- Codes for Massively Parallel Architectures
- Algorithms for Computational Science and Engineering
- Scientific Simulation and Visualization
- Collaborative and Virtual Environments
- High-Performance Computing Systems
- Large-Scale Data Management

Information Sciences
- Information Retrieval
- Advanced Communication Technologies
- Database Management
- Information Architectures
- Geographic and Spatial Information Systems
- High-Reliability and Secure Systems
- Data Visualization
- Digital Libraries

Accelerator Physics and Technology
- Accelerator Systems and Design
- Radio Frequency Superconducting Technology
- Advanced Particle and Photon Detectors
- Magnetic Field Measurement and Analysis
- Radio Frequency and High-Voltage Power Systems
- Particle Bunch Compressors and Long Undulators

High Energy Physics
- Advanced Acceleration Methods
- Formal and Phenomenological Theory
- Numerical Computations in Gauge Theories
- Sampling Calorimetry
- Trigger and Front-End Electronic Systems
- b-Quark Physics
- Direct Photon Production
- Proton Structure Functions
- Properties of Neutrinos
- Nucleon Instability
- Electroweak Symmetry Breaking

Nuclear Physics
- Nuclear and Nucleon Structure
- Spectroscopy of Nuclei at the Limits of Stability
- Nuclear Astrophysics
- Atom and Ion Traps
- Relativistic Heavy Ion Dynamics
- Spin-Dependent Nucleon Structure Functions
- Trace Isotope Analysis
- Theoretical Nuclear Structure and Reactions
- Quantum Monte Carlo Computations of Nuclear Systems
- Non-Perturbative Quantum Chromodynamics
- Heavy Ion and Rare Isotope Acceleration Techniques
- Design and Development of Complex Specialized Instrumentation for Nuclear Physics Research

Table II.1 Capabilities Underlying Argonne Core Competencies (Cont.)

SCIENCES (Cont.)

Major Research Facilities
- Advanced Photon Source
- Intense Pulsed Neutron Source
- Argonne Tandem-Linac Accelerator System
- Electron Microscopy Center for Materials Research
- Hot Fuel Examination Facility
- Transient Reactor Test Facility
- Fuel Conditioning Facility
- Alpha-Gamma Hot Cell Facility
- Structural Biology Center
- Center for Computational Science and Technology
- Low-Energy Undulator Test Line

TECHNOLOGIES

Advanced Nuclear Technology
- Reactor Design and Analysis
- Reactor Safety Experiments and Analysis
- Nuclear Fuels and Materials
- Reactor Decontamination and Decommissioning
- Nuclear Waste Treatment Technology
- Research and Test Reactor Technology

Engineered Materials
- Metals and Metallic Alloys
- Ceramics and Ceramic Composites
- Polymers and Polymer Composites
- Coatings and Surfaces
- Environmental Effects
- Advanced Sensors and Sensor Materials
- Superconductors for Power Applications
- Surface Modification
- Corrosion, Erosion, Friction, and Wear of Engineered Surfaces
- Mechanical Behavior and Life Prediction
- Liquid Metal Technologies

Industrial Technologies
- Instrumentation and Nondestructive Evaluation of Materials and Systems
- Pyrochemical and Electrochemical Processing
- Energy Storage and Cogeneration
- Thermal and Fluid Sciences
- Engineering Mechanics and Mechanical Behavior of Structures and Components
- Process Efficiency and Waste Recycling
- Control Systems
- Biotechnology
- Ultrahigh-Vacuum Science and Technology

Energy Supply Systems
- Fusion Reactor Technologies
- Coal Combustion and Gasification
- Heat and Mass Transfer

Transportation Systems
- Batteries and Fuel Cells for Electric Vehicles
- Maglev Systems Design, Analysis, and Testing
- Advanced Vehicles
- Alternative Fuels
- Environmental Planning in Transportation Systems

Systems Analysis, Technology Assessment, and Decision Sciences
- Economics, Law, and Policy Analysis
- Arms Control and Nonproliferation
- Emergency Systems
- Probabilistic Risk Analysis
- Expert Systems for Artificial Intelligence
- Planning for Utility and Other Energy Systems
- Engineering Analysis and Cost Estimation
- Environmental Policy and Regulatory Analysis

Environmental Technology
- Environmental Control Technology
- Nuclear Waste Management
- Rapid Site Characterization
- Land Reclamation
- Environmental Pathways Modeling and Measurement
- Natural Resource Impacts: Evaluation and Remediation
- Environmental Geographic Information Systems
- Health and Ecological Risk Assessments
- Infrastructure Assurance

III. Science and Technology Strategic Plan

This chapter presents an overview of Argonne's strategic plan; it articulates the Laboratory's vision for the future and describes how Argonne's programs and initiatives support the Laboratory's strategic goals and the missions of the Department of Energy. For 23 Laboratory program areas, this chapter presents summary plans that describe strategies for accomplishing each program's objectives in the context of relevant issues and obstacles to be overcome.

Argonne's planning supports planning by DOE. Overall coordination of the Laboratory's planning with that of the Department relies on several key documents:

- The DOE *Strategic Plan*, the most comprehensive statement of DOE's mission, objectives, long-term performance goals, and strategies. DOE's evolving successor to its 1997 document is available in draft form (URL: www.cfo.doe.gov/stratmgt/plan/doesplan.htm).
- *Research and Development Portfolio*, February 2000, DOE's comprehensive description of R&D across its four business lines, developed as the foundation for an integrated approach to planning, management, and administration (URL: www.osti.gov/portfolio).
- The *Comprehensive National Energy Strategy*, DOE's road map toward energy security, economic expansion, and greater protection of the environment. R&D features prominently in most of the initiatives affirmed by this April 1998 document (URL: www.hr.doe.gov/nesp/cnes.htm).
- The *Strategic Plan* of the Office of Science (URL: www.sc.doe.gov/sidebar/stratpln.htm) and the plans of other DOE program offices.
- Technology road maps of the DOE Office of Energy Efficiency and Renewable Energy (URL: www.eren.doe.gov).
- The annual Budget Request submitted by DOE to Congress (URL: www.cfo.doe.gov/budget/01budget/index.htm).
- The annual *Performance Agreement* between the President and the Secretary of Energy, which establishes for DOE specific commitments and success measures that support the goals and strategies in the DOE *Strategic Plan* (URL for links to the proposed document for FY 2001, the final document for FY 2000, and the reporting of performance for FY 1999: www.cfo.doe.gov/stratmgt).

Argonne's planning is updated frequently, as required by new developments, including shifts in federal R&D priorities and changes in federal budgets.

A. External Environment

> The Department of Energy is, at its heart, a science and technology agency. Science and technology are not merely parts of this Department, they are the foundation on which all the Department's work is based.
>
> Bill Richardson

A number of external issues and uncertainties have affected the design of Argonne's strategic plans or will affect the Laboratory's ability to carry them out. The most globally and immediately pertinent factor is the availability and stability of funding for major initiatives and ongoing programs. Other external developments are discussed below.

The DOE contract reform initiative has fostered productive innovations across the laboratory system. Performance-based contracts that are now the standard have results-oriented statements of work and explicit measures by which the quality of a laboratory's work is assessed. By communicating DOE's expectations, such contracts help laboratory managers focus more effectively on higher priorities and critical objectives. Other elements of DOE's contract reform initiative are encouraging improved productivity through reductions in laboratory overhead costs. (See Section V.H for a discussion of Argonne's participation.)

The DOE contract reform initiative is mirrored by the performance-based planning and budgeting processes that control the Department's coordination with the Office of Management and Budget and with Congress. As required by the Government Performance and Results Act of 1993, DOE's budget submission includes annual performance plans linked to strategic plans.

The study *New Forces at Work: Industry Views Critical Technologies*, released by the Office of Science and Technology Policy (OSTP) in December 1998, documents a notable consensus among 39 senior corporate technology leaders in support of federal roles in which DOE and its laboratories are prominent. Respondents interviewed by OSTP generally agreed that government appropriately serves as a convener of industrial firms to broker solutions to common, precompetitive problems in the technology arena, for example by facilitating the development of industry vision statements, agendas, road maps, and standards. Respondents expressed pervasive support for traditional government roles in laying the groundwork for technological breakthroughs through support for basic research and the infrastructure of science and technology. Many respondents gave high marks to federal cost-sharing research programs, considering them "a good way to balance risk and effort with public and private benefit."

In accordance with the budget reduction agreement between the Clinton administration and Congress and with DOE's Strategic Alignment Initiative, the Department in 1995 committed to major reductions by FY 2001 in both its federal and contractor staffing levels. By January 1999, almost two years ahead of schedule, DOE had met its goals, including a 25% reduction in federal staffing. However, as a result of these staffing reductions, DOE sees skills gaps emerging that could adversely affect the Department's ability to meet its commitments. DOE has launched an initiative to fill gaps in critical federal employee skills that emerged during the downsizing.

The Laboratory Operations Board, established in response to the Galvin report, is serving a continuing, institutionalized role as advisor to DOE on managing its R&D programs. A landmark in 1996 was the Board's development of the *Strategic Laboratory Missions Plan — Phase 1* (URL: www.doe.gov/news/docs/summary.htm) as a baseline for assessing the roles and missions of the Department's national laboratories.

Direct R&D collaborations among the DOE laboratories are becoming increasingly common and important. The Appendix to this *Institutional Plan*, "Argonne in an Integrated DOE Laboratory System," describes many of the more notable collaborations in which Argonne is currently involved. The Appendix also briefly discusses related issues, such as the development of innovative collaboration organizations and new computing and communications technologies that will facilitate future collaborations.

Many factors, beyond R&D funding trends and the Department's planning and management initiatives, shape Argonne's strategic plans. These factors — including those in the scientific, technical, political, and economic arenas — are discussed in the area plans presented in this document. The remainder of this chapter includes plans for the Laboratory's scientific and technical programs. Chapter V includes plans for operations and infrastructure.

B. The Argonne Vision

Argonne's vision is to be a world-class provider of high-quality science, technology, engineering, and technical services, with the excellence of its research recognized by the Department of Energy, by other public and private sponsors, and by the many scientists and engineers from across the country who are research collaborators or users of Argonne's facilities.

To achieve this vision, Argonne must earn and maintain trust as a national research performer, as a fully integrated research partner with other DOE laboratories, as a regional science and technology resource, and as a valued neighbor in the community. To meet this goal, the Laboratory will

- Manage the recruitment and development of human resources to maximize the long-term creativity and productivity of Laboratory staff;

- Provide continuous improvement in management and administrative systems as a prerequisite to achieving and maintaining efficient, cost-effective performance; and

- Evaluate and reward organizational and individual performance on the basis of objective performance measures.

C. Strategic Objectives by DOE Mission Area

Argonne supports the Department of Energy in pursuit of the Department's defined statutory missions.

For each DOE mission area, this section provides a general statement of Argonne's overall R&D goal, followed by a brief description of the Laboratory's strategic objectives. Some of these objectives involve the development of R&D initiatives, a number of which are discussed in the context of the Laboratory's area plans in Section III.D. The Laboratory's major initiatives are described in Chapter IV.

1. Science: Creating Ideas, Jobs, Products, and Industries for Tomorrow

GOAL: To contribute significantly to the science and technology base needed to accomplish DOE and other national technology development goals; to develop and operate national user facilities that support the advancement of U.S. science and technology; to develop innovative experimental concepts and instrumentation that support fundamental research in energy and matter; to assist in the training of undergraduate and graduate students in science and engineering.

Fundamental Science

- In the burgeoning field of nanoscience, develop a thorough understanding of the principles by which the communication between nanoscale devices in highly complex systems may be organized and controlled, including both the sending and accepting of information.

- Strengthen Laboratory capabilities for materials synthesis, processing, and characterization, including primary synthesis procedures applicable to many kinds of materials.

- Conduct research to establish the fundamental physics of advanced materials having properties that are important scientifically and technologically.

- Conduct research to resolve fundamental questions concerning the characteristics and dynamics of nuclear and subnuclear degrees of freedom in nuclei and nuclear matter, as well as the role of these properties in nuclear astrophysics.

- Provide leadership for frontier research and development in the physics of elementary particles by designing, building, and utilizing advanced particle physics detectors; developing and interpreting theories of particle physics; and inventing and demonstrating advanced concepts for particle accelerators.

- Develop open-source algorithms and tools for advanced computer architectures, particularly for parallel systems and large-scale clusters, and apply these capabilities in areas such as global climate modeling, combustion chemistry, materials science, and computational biology.

- Increase dramatically the rate at which the structure and function of biomolecules are determined by developing computational methods for selecting protein targets from genome data, automated protein expression systems, high-throughput techniques for protein purification and crystallization, additional X-ray crystallography facilities at the Advanced Photon Source (APS), and rapid computational methods for structure refinement and modeling.

- Greatly speed the discovery of valuable complex materials by integrating combinatorial synthesis with materials characterization enabled by the APS.

- Develop biological microchips (biochips) to speed the identification of mutations in human genes and to allow the identification of viruses, bacteria, and bacterial toxins. Develop and apply integrated, automated biochip technology for human gene research, medical diagnostics, pharmaceutical discovery, disease treatment, microbial identification, environmental restoration, and agricultural innovation.

• Bioengineer devices and procedures in the emerging area of collaborative engineering for resuscitation — to cool the heart and brain during cardiac arrest or stroke, to monitor oxidant stress during sudden cardiac arrest, and to enhance electrocardiogram traces as predictors of potential for recovery.

• Develop, from a base of traditional environmental research, a synchrotron-based program in environmental molecular science.

• To support better carbon management, provide leadership in developing deeper understanding of carbon cycles through the environment, including both biochemical and geochemical pathways.

• Develop new materials on the nanoscale, by using the Laboratory's deep capabilities in synthesis, characterization, and prediction to foster the industrial revolution in nanotechnology.

• Develop accelerator and undulator technologies to demonstrate the process of self-amplified spontaneous emission (SASE), for wavelengths ranging from the optical to X-rays.

Major Research Facilities

• Operate the APS — a superintense source of high-energy X-rays — to meet the evolving needs of a very large and diverse community of users. Optimize operational reliability and orbit stability and continue to improve accelerator systems and experimental capabilities.

• Develop APS research facilities for collaborators from across the United States. Complete centers for research with synchrotron radiation in basic energy sciences and structural biology; develop the associated instrumentation and techniques through efforts by research groups from inside and outside the Laboratory.

• Through interagency collaboration, provide additional laboratory facilities to APS users from the biological disciplines.

• At the APS, use the low-energy undulator test line to investigate SASE in a free-electron laser as the basis for the Linear Coherent Light Source at the Stanford Linear Accelerator Center.

• Develop a facility to accelerate beams of unstable nuclei, capitalizing on the capabilities of the Laboratory's existing heavy-ion accelerator, the Argonne Tandem-Linac Accelerator System, by using it as the postaccelerator in a two-accelerator design.

• Operate laboratories in computing and communications to explore integration of multimedia technology with scientific supercomputing, virtual environments for scientific visualization and collaboration, and advanced communications technologies based on high-performance networks.

• For the Spallation Neutron Source, lead the development of instrumentation, train an expanding user community, and take a leadership role in the development and operation of a second target station optimized for long-wavelength neutron scattering; at the Intense Pulsed Neutron Source, improve the long-term reliability of the accelerator system and improve existing instruments, doubling the capabilities of most.

• Build on expertise in atmospheric science, remote sensing, advanced computation, information processing, and facility management to develop a national meteorological user facility.

• Support a broadly based Electron Microscopy Center for Materials Research that includes the High Voltage Electron Microscope-Tandem Facility; develop advanced instrumentation and techniques for *in situ*, analytical, and high-resolution transmission electron microscopy.

• Through interlaboratory collaboration, develop new national user facilities for electron beam microcharacterization of nanoscale materials, and develop national capabilities in industrially important charged-particle optics.

2. Energy: Secure Supplies of Clean, Affordable Energy

GOAL: To develop technologies that improve the safety, proliferation resistance, and environmental acceptability of fission energy systems and that reduce their costs; to develop, test, and carry to proof of concept new energy efficiency technologies.

Nuclear Technology

- Perform leading-edge research in nuclear energy science and technology, and develop innovative concepts for future nuclear reactors.
- Address the critical technology issues associated with existing nuclear power plants.
- Develop the International Nuclear Safety Center to provide improvements in reactor safety worldwide, with an immediate focus on Soviet-designed reactors.
- Serve as lead laboratory for reactor technology under charter to the DOE Office of Nuclear Energy, Science and Technology, in collaboration with the Idaho National Engineering and Environmental Laboratory.

Energy Efficiency

- In cooperation with U.S. transportation industries, develop cost-effective technologies to improve fuel efficiency and decrease environmental emissions, focusing on electric batteries and fuel cells, advanced compression-ignition engines, hybrid vehicle systems, alternative fuels, computational techniques for vehicle design and manufacture, and improved recycling of obsolete vehicles.
- In cooperation with U.S. industry, expand research to improve technologies that reduce energy consumption and waste production in the petrochemical, forest products, metals, and other energy-intensive industries.
- Develop the technology required to produce low-cost biobased chemicals through the advancement and integration of molecular biology, materials nanotechnology, bio-informatics, robotics, biomimetic chemistry, chemical engineering, and bioprocessing.

Superconductivity Technology

- Develop high-temperature superconducting materials with current densities and mechanical properties suitable for application in electric utility systems.

Environmental and Energy Systems

- Develop technologies to reduce environmental and economic impacts associated with (1) use of depletable natural resources, particularly energy resources, and (2) emissions from energy production and use at local, regional, national, and international scales.
- To decrease emissions of carbon dioxide and other greenhouse gases from use of fossil fuels, support the examination of carbon management strategies for the utility, industrial, and transportation sectors.

Fossil Energy

- Undertake fundamental studies of technical issues limiting advanced fossil fuel technologies, such as materials performance and inspection capabilities. Improve predictive understanding of mass, heat, and fluid transport phenomena.
- Support DOE strategies to reduce environmental constraints to expanded use of fossil fuels through research on (1) economic processes for separating oxygen from air and hydrogen from mixed gases (which are critical for utilization of remote natural gas); (2) catalytic hydroprocessing of petroleum and nonpetroleum feedstocks, to produce ultraclean transportation fuels; and (3) methane hydrates, to increase domestic natural gas resources.

Fusion Energy

• Develop advanced materials and critical technologies for high-performance, environmentally attractive in-vessel fusion power systems (first wall, blanket, and divertor).

3. Environmental Quality: Accelerating Progress, Meeting Commitments

GOAL: To continue to strengthen existing programs and broad capabilities in environmental sciences and technology, while undertaking research that contributes significantly to the cleanup of DOE sites and the solution of other national environmental problems.

Environmental Science and Technology

• Develop improved energy system models and planning tools that predict environmental impacts; research the transport, deposition, and environmental effects of energy-related pollutants; and enhance techniques and tools, such as remote sensing and geographic information systems, for monitoring and analyzing the sustainability of natural resources over time.

• Test and adapt novel technologies for environmental remediation that remove, detoxify, and recover undesirable matter — such as heavy metals, organic compounds, and bacteria — from pipelines, soils, groundwater, and aqueous waste streams.

• Develop the Argonne electrometallurgical treatment technology to condition DOE spent fuel into a standard form that eliminates concerns about chemical reactivity and that allows disposal in a geologic repository at substantially reduced cost.

• Develop safe, cost-effective technologies for decontamination and decommissioning (D&D) and use Argonne nuclear facilities as test beds for these and other technologies. Deploy D&D technologies and provide technical services for DOE sites and electric utilities.

• Develop a comprehensive program to investigate hazards, exposure pathways, and impacts for the assessment and management of risks to public health, environmental quality, and occupational safety.

DOE Sites

• Help DOE implement waste management and environmental restoration, including innovative site characterization techniques; provide innovative decision tools, environmental pathway models, risk assessments, and environmental technologies for more cost-effective and timely approaches to waste minimization, pollution prevention, cleanup, and long-term stewardship at DOE sites.

• Develop (1) technologies and facilities for handling and treating mixed wastes and (2) new waste forms, with technologies, facilities, and waste forms all tailored to the needs of specific DOE facilities and waste streams.

• Support DOE programmatic initiatives by preparing environmental impact statements for major DOE facilities.

4. National Security: Addressing 21st Century Challenges

GOAL: To enhance U.S. national security by applying the Laboratory's unique technical resources in nuclear technology and other areas to solve problems encountered in arms control, nonproliferation, verification, defense, and domestic infrastructure assurance.

• Extend the Reduced Enrichment for Research and Test Reactors program to additional Russian research reactors, to other countries not previously participating, and to reactors for which fuels with suitably high uranium densities have been unavailable.

• Support U.S. nonproliferation policy objectives worldwide, including development of methods for protecting nuclear materials and sensitive nuclear technologies.

• Apply Argonne's technology and expertise to problems associated with the safety (both

Argonne's Strategic Plans

1. **Fundamental Science and National Research Facilities**
   a. Advanced Photon Source
   b. Materials Science
   c. Basic Energy Sciences Synchrotron Radiation Center
   d. Electron Microscopy Center for Materials Research
   e. Chemical Sciences
   f. Nuclear Physics
   g. Argonne Tandem-Linac Accelerator System
   h. High Energy Physics
   i. Mathematics, Computing, and Information Sciences
   j. Intense Pulsed Neutron Source
   k. Biosciences
   l. Biotechnology
   m Environmental Research
   n. Science and Engineering Education and University Programs
2. **Energy Technologies**
   a. Energy and Industrial Technologies
   b. Advanced Nuclear Technology
3. **Environmental Technologies**
   a. Electrometallurgical Technology
   b. EBR-II Termination
   c. Radioactive and Mixed Waste Treatment Technologies
   d. D&D Technology
   e. Energy and Environmental Systems — Assessment, Information, and Technologies
4. **National Security:**
   Arms Control and Nonproliferation
5. **Collaborative R&D Partnerships**

nuclear and environmental) and the management of excess fissile materials and spent fuel in the former Soviet Union.

• Participate in the Initiative for Proliferation Prevention and the Nuclear Cities Initiative.

• Apply Argonne's extensive nuclear facilities to the demonstration and validation of nuclear measurement and detection techniques.

• Expand Argonne's capabilities to develop a broader range of technologies and tools for addressing threats to the nation's infrastructures related to the transmission and distribution of electric power, oil, gas, and water, including threats from acts of international terrorism and from natural and technological disasters.

D. R&D Area Strategic Plans

The balance of this chapter presents summaries of strategic plans for each of 23 planning units that span the Laboratory's major mission areas (see the inset box). These strategic plan summaries are grouped into (1) Fundamental Science and National Research Facilities, (2) Energy Technologies, (3) Environmental Technologies, and (4) National Security. This grouping corresponds to the four business lines of DOE. In addition, a concluding summary plan addresses the crosscutting topic of Collaborative R&D Partnerships.

The planning areas for fundamental science and national research facilities correspond closely with Argonne's scientific divisions. In contrast, Argonne's technology programs cut across Laboratory divisions to exploit multidisciplinary capabilities. (See the organization chart for Argonne at the end of this volume.)

A number of the R&D area plans that follow include discussions of programmatic initiatives. These discussions complement presentation of Argonne's major initiatives in Chapter IV. A cross-index to the programmatic initiatives is at the end of Chapter IV.

1. Fundamental Science and National Research Facilities

Argonne's activities in the area of Fundamental Science and National Research Facilities are supported predominantly by DOE's Office of Science. The nature of this work, including its crosscutting relevance to other DOE missions, has been distilled by the Office of Science into four themes:

- Exploring Matter and Energy: Building Blocks of Atoms and Life
- Extraordinary Tools for Extraordinary Science: National Assets for Multidisciplinary Research
- Fueling the Future: Science for Affordable and Clean Energy
- Protecting Our Living Planet: Energy Impacts on People and the Environment

"Science for America's Future" is the overarching theme.

a. Advanced Photon Source

Situation

The APS is Argonne's highest-priority research facility. Its continued successful operation is central to the Laboratory's performance in science and technology. Prestigious national advisory committees endorsed this high-brilliance X-ray source as the highest priority among the present generation of materials science research facilities. The APS is delivering on its promise to enhance U.S. productivity in a broad spectrum of scientific and technological areas. International competition in these research areas comes primarily from two similar X-ray centers: the European Synchrotron Radiation Facility and SPring-8 in Japan, both now operating.

The APS began operating in 1996 as a national user facility available to the entire U.S. community of X-ray researchers. The U.S. government made a major investment of $812 million to construct the APS over the seven-year period from 1989 to 1996. The resulting world-class photon source today provides the brightest X-ray beams available in the Western Hemisphere for a wide range of research from materials science to structural biology. Collaborative access teams — composed of investigators from private industry, universities, government, and other institutions — have initiated many research programs at the APS. Forty-eight of the 70 X-ray beamlines available at the APS have been allocated to collaborative access teams. Six additional beamlines have been requested by structural biology research groups. The remaining beamlines can be developed for new research programs. The number of users is expected to increase from approximately 2,000 in FY 1999 to roughly 4,000 when all 70 beamlines have been fully developed. Built and operated for DOE-Basic Energy Sciences, the APS is accessible to all qualified users of synchrotron radiation.

Vision

The APS will function as a dependable and preeminent source of synchrotron radiation for the X-ray research community. It will serve research across a wide range of frontier science and technology, addressing questions of importance both nationally and internationally. It will be known for highly reliable operation and high availability of accelerator and beamline systems over a large number of operating hours; high-quality user support; and innovative R&D supporting both continuous improvement of accelerator systems and enhancement of experimental capabilities. Through productive partnerships with its users, the APS will better serve these primary customers, thereby creating a rewarding and enriching R&D environment and enhancing the facility's worldwide leadership role.

Mission

The mission of the APS includes the following major elements:

- Operate and improve a source of high-brilliance X-ray beams that meets the evolving requirements of a very large and diverse user community.
- Optimize operational reliability, availability, beam quality, and scheduled operating time to achieve excellence in serving all research users.
- Develop leading-edge accelerator and experimental technologies that advance X-ray research capabilities of investigators from across the United States and around the world.

Goals and Objectives

The overall goals of the APS are (1) to increase beam availability, beam quality, and scheduled operating time; (2) to use insertion devices and bending magnets to provide synchrotron radiation dependably to APS users; and (3) to provide the technical and administrative support needed to maximize the productivity of the researchers. Major objectives are as follows:

- Maintain accelerator operations at better than 95% availability in 2001.
- Maintain operating time scheduled for users at 5,000 hours per year in 2001.
- Operate the APS storage ring in the "top-up" mode to keep the current level constant.
- Advance APS accelerator systems beyond original specifications for orbit stability, emittance, and beam current.
- Advance the bunch-filling capabilities of the APS to meet the diverse needs of users.
- Continue seamless support to APS users in the areas of technical support, safety, administration, and general services.
- Advance the state of the art in the production and specialized use of synchrotron radiation, through strategic research.

In all these endeavors, highest priority is given to ensuring the health and safety of employees, users, and visitors and to protecting the environment.

Issues and Strategies

The APS is a high-quality research facility with excellent, experienced staff. All technical design parameters of the accelerator systems have been achieved, and accelerator physics at the facility now focuses on achieving ever-increasing levels of operational reliability and availability. The near-term objective of routine operations with reliability near 95% and top-up operation was achieved in FY 1999. By FY 2001, the objective is 95% availability with up to 5,000 hours of operating beam time scheduled for users each year. In addition to hardware upgrades, R&D opportunities for improvement include operation with small-gap chambers, monitoring of beam stability, orbit control, orbit control feedback, and top-up operation.

The APS will maintain the excellence of its accelerator research capabilities by pursuing midterm objectives involving extension of electron beam performance to higher current and lower emittance. Longer-term research objectives will involve tests to evaluate novel undulator concepts — such as small-gap, superconducting, helical, or long-undulator — and segmented or multiple undulator systems.

Two of Argonne's major initiatives discussed in Section IV.A will be centered at the APS: (1) Fourth-Generation X-ray Source and (2) Laboratory Complex for Biostructure Research. Two other major initiatives will make extensive use of the APS: (1) High-Throughput Systems for Biomolecular Research and (2) Synchrotron Environmental Science.

b. Materials Science

Situation

Research in materials science at Argonne addresses critical issues underlying the development of new and improved materials that play crucial roles in both the national economy and DOE mission areas. The Laboratory's work embraces experimental and theoretical studies and also increasingly important computer simulations. Simulations can improve materials reliability and the efficiency of materials design, with major economic benefits. Materials science research at Argonne emphasizes programs that require the broad scale and depth of investigation that are possible within the national laboratories.

Argonne's user facilities for materials research feature prominently in Laboratory research programs. Argonne researchers have many collaborators among outside users at the Laboratory's facilities, from universities, and in industry. Collaborators are most commonly from the Illinois area, but they also come from across the nation and around the world.

Key materials research areas at Argonne include superconductivity, magnetism, ferro-electricity, ceramic films, metals, carbon, and nanoscale materials science and technology. Crosscutting research themes are emphasized, especially complex oxides, interfaces, and defect production.

Vision

Argonne will foster world-class science, forefront instrumentation, and unique user facilities. The combination of individual freedom and teamwork that nurtured past successes will be strengthened. The Laboratory's contributions to new materials, especially at the nanoscale, will greatly benefit both DOE and the nation in meeting their goals.

Objectives

Specific objectives of Argonne's research are as follows:

- Exploit nanosciences through increased understanding of materials properties in confined structures, thus creating new applications.
- Develop and apply innovative experimental uses of the Laboratory's unique X-ray, neutron, and electron microstructural characterization capabilities — at the Advanced Photon Source, Intense Pulsed Neutron Source, and Electron Microscopy Center for Materials Research, respectively — and take full advantage of the proximity of these capabilities.
- Understand the fundamental properties of high-temperature superconductors; explore and develop their applications, while taking further advantage of understanding these complex oxides to investigate related materials, such as layered manganites and ferroelectrics.
- Understand the fundamental basis of magnetism, especially in thin films and nanostructures, and thereby develop new and better magnetic materials.
- Identify fundamental principles controlling the behavior of complex systems such as granular materials.
- Improve the interface and surface properties of materials, particularly in order to improve materials processing, catalytic action, and environmental benefits.
- Establish an integrated understanding of the modifications to materials that result from irradiation with electrons, ions, and neutrons; develop means of mitigating radiation damage.

Issues and Strategies

Funding remains a primary concern for materials science at Argonne. Innovative initiatives and enhancement of smaller facilities into more effective user centers will require increased core funding from the DOE Office of Basic Energy Sciences (DOE-BES). The Laboratory's major initiative Nanosciences and Nanotechnology — Center for Nanoscale Materials is discussed in Section IV.A.4. Increased support is also needed for contributions to a broader range of DOE technology missions and for collaborations with outside organizations.

Argonne is continuing to integrate its materials science research more effectively with applied materials programs and other R&D programs throughout the Laboratory. Formal mechanisms now coordinate basic and applied work in engineered materials and related fields.

Argonne is participating extensively in efforts to strengthen partnerships among the materials science programs of all the national laboratories. An important mechanism is strong participation in the Center of Excellence for Synthesis and Processing and the newly formed Computational Materials Science Network, both sponsored by the Division of Materials Sciences within DOE-BES. Argonne is involved in several thrusts aimed at integrating the development of interlaboratory programs with industrial collaborations. Argonne is the primary coordinator for two programs, one to develop better permanent magnets, the other to understand plastic deformation in nanophase materials.

Argonne's work in superconductivity has benefited from close coupling with the Science and Technology Center for Superconductivity, which has been supported by the National Science

Foundation but whose activities end in FY 2000. However, collaboration will continue with partners at the University of Chicago, Northwestern University, and the University of Illinois, as will the search for further partnerships with outside institutions.

Initiative: Laterally Confined Nanomagnets

Argonne proposes to investigate basic issues at the frontiers of the emerging field of laterally confined nanomagnets. The central goal is to identify the fundamental new physical phenomena associated with the competition between spatial and magnetic length scales and proximity effects and to understand how the physics changes as the ultimate limits of miniaturization and structural perfection are approached. The Laboratory will study interactions between elements in a nanoarray, as well as within the internal structure of isolated entities. This work will help transform the art of nanomagnet fabrication into a science.

The plan for this work has several tiers, each involving the interplay of experiment, major facilities, theory, and simulations. First, lithographies will be used to create submicron arrays of novel composite heterostructures (e.g., Co/Pt multilayers and SmCo/Fe exchange-spring magnet bilayers). These systems will then be used to explore domain wall energetics, magnetization-reversal and -relaxational dynamics, and pinning in confined geometries. Lithographies will also be used to fabricate unique tunnel junctions that are magneto-electronic (or spintronic) prototypes (such as Argonne's conceptual voltage-controlled interlayer magnetic coupling structure, patent pending), in order to explore magnetotransport and its relationship to interfacial roughness.

Two self-assembly approaches will be pursued to transcend lithographic length scales in a quest for the atomic limit of spatial confinement and structural perfection. One approach is self-assembly of epitaxial metallic nanoarrays via surface science strategies (e.g., Fe/110/Pd) to create lateral stripes and novel tilted superlattices, in order to explore quantum confinement, lateral exchange couplings, finite-size scaling, and time-dependent magnetization effects. The structures will be prepared via step decoration and via codeposition of immiscible metals onto novel substrates, including organic crystal templates with variable-scale periodicities that serve as molecular rulers. The other, complementary, approach uses the unprecedented manipulation of the chemical selectivity of diblock copolymers to create nanomagnetic arrays of spheres, cylinders, and lamellae.

Finally, molecular magnets will be selected to explore physical changes due to the dominance of quantum tunneling effects. Novel nanocharacterization tools to be used include near-field and diffraction-mode magneto-optics of lithographic nanoarrays and the spin-polarized scanning tunneling microscopy of self-assembled arrays. Synchrotron X-ray scattering and dichroism at the APS will be used to correlate structural and magnetic roughness with step-edge and roughness-induced magnetic anisotropies. Electron holography at the Laboratory's advanced analytical electron microscopy facilities will be used to image the fields that emanate from nanomagnet arrays. Polarized neutron scattering will determine magnetic-depth profiles across interfaces and spin density maps of molecular magnets. This work will be performed first at Argonne's Intense Pulsed Neutron Source and eventually at the Spallation Neutron Source. Argonne's large-scale simulational facilities will be used for diverse modeling of fast-switching dynamics and of pinning, quantum tunneling, and magnetotransport phenomena.

Funding is sought from DOE-Materials Sciences (KC-02). Resources required are summarized in Table III.1.

Table III.1 Laterally Confined Nanomagnets
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	0.6	1.2	1.2	1.2	1.2	1.2	1.2
Capital Equipment	0.1	0.2	0.5	0.3	0.2	0.2	0.2
Construction	-	-	-	-	-	-	-
Total	0.7	1.4	1.7	1.5	1.4	1.4	1.4
Direct Personnel	3.0	6.0	6.0	6.0	6.0	6.0	6.0

c. Basic Energy Sciences Synchrotron Radiation Center

Situation

The APS is dramatically enhancing research within DOE-BES programs. The Basic Energy Sciences Synchrotron Radiation Center (BESSRC) at the APS is being developed as a joint venture of Argonne's Chemistry and Materials Science Divisions, in partnership with Argonne's BES-Geosciences program and Northern Illinois University. The BESSRC facility at the APS — consisting of two bending magnet beamlines, one undulator, and an elliptical multipole wiggler — is designed to provide state-of-the-art capabilities for both traditional and forefront methods of synchrotron-based science.

Construction of BESSRC facilities is almost complete, and both insertion devices and one bending magnet are already heavily used. The undulator beamline and bending magnet are fully commissioned; they accepted their first external users in 1999. The wiggler insertion device is currently being commissioned and is expected to open for external users in FY 2000.

Forefront capabilities at the BESSRC include the following:

- Inelastic X-ray scattering
- Real-time studies in short time domains
- *In situ* studies of chemical and physical processes, including those at solid-fluid interfaces
- High-energy X-ray diffraction
- Photoionization and photoexcitation in atomic and molecular physics
- Characterization of actinides by X-ray absorption spectroscopy
- Structural characterization of proteins and complex carbonaceous compounds by means of X-ray scattering

Vision

The BESSRC facility will provide forefront capabilities enabling innovative research and important breakthroughs in broad areas relevant to DOE-BES programs, including chemistry, materials science, atomic physics, and geoscience.

Issues and Strategies

Technical aspects of the BESSRC are proceeding very well. A primary issue is the availability of sufficient funds for operation. Funding is being sought from DOE, from other federal agencies, and from partnerships developed with other institutions. Planning is beginning for future upgrades, including development of the second bending magnet, which will require a capital investment of $3 million.

d. Electron Microscopy Center for Materials Research

Situation

Argonne's Electron Microscopy Center for Materials Research (EMC) provides transmission and scanning electron microscopy for high-spatial-resolution imaging, microanalysis, and *in situ* research. The EMC includes the High Voltage Electron Microscope (HVEM)-Tandem Facility, which is used for dynamic recording and structural characterization of the effects of electron and ion irradiation and is the only facility with those capabilities in the Americas. Qualified users access the HVEM-Tandem Facility by submitting written proposals that are peer reviewed. For nonproprietary research, users of the facility are not charged. EMC users — including researchers from universities, other national laboratories, and industry — conduct studies ranging from imaging of electron-sensitive soft materials to *in situ* observation of phenomena at elevated and cryogenic temperatures in metals, semiconductors, and ceramics.

Vision

The EMC will offer state-of-the-art instrumentation and development of new techniques for transmission and scanning electron microscopy analysis, including capabilities for *in situ* analysis. The materials research supported will provide important new insights for major technologies in such areas as micromagnetics, irradiation effects in high-temperature superconductors, solid-state amorphization reactions, and control of nanostructures.

Issues and Strategies

The addition of a high-resolution, intermediate-voltage electron microscope to the HVEM-Tandem Facility has been very productive and has partially substituted for the much older HVEM in a variety of research studies. However, Argonne continues to seek a replacement for the HVEM that will ensure the long-term availability of high-voltage electron microscopy in the United States. Planning is under way for acquisition of a state-of-the-art transmission electron microscope based on a field emission gun that will dramatically improve the analytical capabilities available to users of the EMC. The recent acquisition of a scanning electron microscope based on a field emission gun is already broadening analytical capabilities significantly.

Initiative: National Transmission Electron Achromatic Microscope

Thanks to advances in aberration correction and quantitative-transmission electron microscopy, a new generation of electron microscopes can be built that are capable of sub-angstrom image resolution and sub-electron-volt spectroscopic resolution and that have space adequate for a variety of important experiments on advanced materials. To take advantage of these new technologies, Argonne proposes a National Transmission Electron Achromatic Microscope (NTEAM). The required instrumental development could be carried out cooperatively at DOE's four national centers for electron beam microcharacterization, with each center contributing a complementary specialized facility based on a common platform.

The revolutionary combination of space and resolution envisioned for the NTEAM will allow the electron microscope to be converted into a true experimental materials science laboratory. Scientific impacts to be expected include the first three-dimensional atomic imaging of defect structures; the first atomic structure determination of a glass; microscopic understanding of magnetism and ferroelectricity in nanostructures; visualization of dislocation interactions in nanostructures under controlled stress; development of interface science to the level of surface science; understanding of grain boundary motion under stress in nanocrystals; understanding of chemical reactions on highly curved, small catalyst particles; and imaging of defects in the oxygen sublattice of complex oxides. More generally, advances in electron beam microcharacterization associated with the development of NTEAM would be crucial for proper implementation of the planned national thrust in nanotechnology. The NTEAM project would also help to revitalize the critically important electron optics industry in the United States.

Funding for this initiative will be sought from DOE-Materials Sciences (KC-02). Partnerships with industry and universities are also sought.

e. Chemical Sciences

Situation

Chemistry has been an Argonne core capability since the Laboratory's earliest days. Today the Laboratory conducts cutting-edge, fundamental research in areas that support the DOE mission: radiation and photochemistry; natural and artificial photosynthesis; the chemical physics of combustion processes; theoretical and computational chemistry; carbon energy chemistry and complex materials; heavy-element photochemistry, photophysics, and interactions; the separations science of heavy elements; metal cluster chemistry; electrochemistry; atomic, molecular, and optical physics; scanning-probe microscopy; fluid catalysis; chemical nanoscience; and carbon management. A focus on long-range, mission-driven, fundamental research has created strong research programs that readily contribute to new, multidisciplinary research challenges in areas such as environmental science and research related to nuclear waste issues and nuclear energy. Many of the Laboratory's core research capabilities are broadly relevant to nanoscience. Results from Argonne chemical sciences research will underpin advances in energy efficiency, energy conversion, understanding of global climate change, cleanup and disposal of radioactive and nonradioactive waste, and industrial chemical analysis.

Vision

Argonne will continue to be a leading U.S. performer of chemical sciences research, as judged from metrics such as peer review and citation counts, and will provide major economic and environmental benefits to the United States by conducting a chemical sciences program of the highest quality.

Objectives

Specific long-range objectives of Argonne's core research are as follows:

- Advance understanding of the elementary chemical reactions and related nonreactive energy transfer processes involved in combustion, through theoretical work on the energetics and dynamics of chemical reactions, plus experimental work on chemical dynamics and kinetics.
- Elucidate the important molecular and physical structural features of disordered cabonaceous materials such as soots, heavy hydrocarbons, and coals through use of state-of-the art tools including synchrotron X-ray spectroscopy and scattering, neutron scattering, solid-state nuclear magnetic resonance spectroscopy and imaging, and laser desorption time-of-flight mass spectrometry.
- Establish a refined, quantitative understanding of X-ray interactions with atoms and molecules, and provide a fundamental basis for the X-ray methods used in spectroscopic and scattering applications.
- Identify the mechanisms responsible for optimization of photochemical energy conversion in natural photosynthesis, and use this information to develop artificial photochemical systems capable of enhanced photochemical energy conversion.
- Advance the basic state of the art in metal ion separations science by conducting fundamental investigations of the interactions of metal ions with chelating agents and solvent molecules, by designing and characterizing new reagents for more effective separations, and by examining the physical and chemical characteristics of metal ion separation processes.
- Improve understanding of the interplay between f-elements and their environment, through use of innovative experimental approaches including laser-based methods (such as nonlinear laser spectroscopy and optically detected nuclear magnetic resonance) and *in situ* X-ray absorption fine structure spectroelectrochemistry at the APS.
- Improve understanding of the molecular processes and the initial physicochemical phenomena that occur when energetic radiation interacts with matter, through use of state-of-the-art pulsed electron accelerators and very intense high-energy lasers providing excitation in the fastest time domains.
- Examine the chemical and physical properties of clusters of catalytically active transition metal atoms through combined experimental and theoretical studies that address, for example, how cluster properties evolve with size and how cluster chemistry depends on structure.
- Explore fundamental catalytic reaction chemistry aimed at helping the chemical process industry become more energy efficient and more environmentally benign, by using an array of *in situ* high-pressure spectroscopic and kinetic techniques.
- Employ complementary experimental and theoretical approaches to study, at a fundamental level, the electrochemical processes in electrodes and electrolytes relevant for lithium batteries and fuel cells.

Goals, Issues, and Strategies

Argonne's goal is to sustain preeminence in its established research focus areas while undertaking several important new activities.

Three facilities for research at the APS were recently completed with funding from the Enhanced Research Capabilities at DOE User

Facilities Initiative. Argonne is conducting investigations in three main research areas:

- Transient molecular structures in photochemically induced reactions important in solar energy conversions
- The molecular and environmental science of actinides
- Static and dynamic order in condensed phases, studied by using a time-resolved anomalous small-angle X-ray scattering facility

Argonne is defining the state of the art in pulse radiolysis through the design and construction of a tabletop terawatt laser for generating electrons for ultrafast (subpicosecond time resolution) pulse radiolysis experiments. Fundamental understanding of the generation and solvation of charged species is key to an array of chemical processes related to energy conversion in the condensed phase. These initial stages of the interaction of radiation with matter determine the ensuing chemical fate and the nature of chemical processes. The complementary approaches employed by Argonne to study these ultrafast processes are transient optical spectroscopies and pulsed radiolysis. Each approach has advantages. For example, when the hydrated electron, a species of tremendous theoretical and practical importance, was discovered, its chemical properties were measured with pulse radiolysis techniques. On the other hand, transient optical spectroscopy has to date contributed considerably to understanding the formation dynamics of the hydrated electron. This situation was reversed when the electron transfer chemistry of solar-conversion processes was first explored. Pulse radiolysis provided clearer and simpler demarcation of intermediate chemical steps than did optical excitation. The complementarity of the two research approaches reinforces the need for transient radiolytic spectroscopy to keep pace with optical spectroscopies. Indeed, recent Argonne work suggests that differences exist between laser photoionization and radiolytic ionization in polar liquids. Understanding these differences will provide insight into microscopic factors that influence ensuing chemical reactions. These fundamental issues impact other important areas of study, such as radiolytic processes in radioactive waste, radiation processing, and radiation biology.

Although initial experiments with the new tabletop terawatt laser system will focus on ultrafast studies of electrons in polar liquids, successful realization of this novel capability will also be used to explore the radiation chemistry of other important systems, including nonpolar liquids and solids (such as silicon-based materials relevant to photovoltaics and nanomaterials). As the new system is being constructed, the Laboratory will develop methods of characterizing the subpicosecond electron pulses, which will provide valuable insight into the physical processes underlying generation of such pulses. In addition, the laser system will be able to generate X-rays, enabling ultrafast studies of the interaction of X-rays with atoms and molecules.

Argonne’s integrated program in the fundamental chemistry of radioactive waste is partly supported by the DOE Environmental Management Science Program. The Laboratory is uniquely qualified to undertake this program, on the basis of its core capabilities in chemical separations science, heavy-elements chemistry, radiation chemistry, and theoretical chemistry, as well as its facilities for research with radioactive materials (including the facility for actinide studies at the APS and the nuclear magnetic resonance facility for studying radioactive materials). This program of experimental and theoretical research responds to a national need for deeper fundamental knowledge of the chemistry underpinning technologies for the cleanup and disposal of radioactive waste. Further related issues requiring research include developing more efficient, cost-effective separation techniques for treating mixed waste, transuranic waste, and high-level waste; creating and characterizing new waste forms; improving understanding of oxide degradation processes that could limit some plutonium disposal options; and developing monitoring and characterizing sensor systems for research in waste management applications.

Argonne has developed a research program that addresses all of the issues relating to radioactive waste identified above. Nonlinear laser spectroscopy of actinide ions within representative glass matrices is being used to develop correlations between electronic energy levels and structural defects induced by microscopic radiation damage in glass waste forms. Argonne has also begun investigating radiation effects in waste forms — especially bubble formation and transport in silicate glasses. Use of X-ray absorption spectroscopy has shown that modifying a clay mineral surface by adding an organic coating is a good technique for sequestering uranium. The Laboratory is also designing and characterizing ligands that are soluble in supercritical carbon dioxide and are suitable for actinide extractions. In additional work for the DOE Environmental Management Science Program, Argonne is studying complexants for actinide separations and is characterizing processes in alkaline waste tank sludges.

Argonne is developing advanced relativistic quantum code for simulation of systems containing a large number of atoms (including several that are heavy elements), thereby increasing the contribution of chemical theory to the radioactive waste management program (work supported in part by a Grand Challenge from the DOE Office of Computational and Technology Research [Mathematical, Information, and Computational Sciences Division]).

Argonne has developed two research programs in response to the Nuclear Energy Research Initiative (NERI). One focuses on an innovative, single-material, minimum-volume approach to the selective sorption of most metal ion radionuclides from aqueous waste solutions and on creation of a final nuclear waste form that is suitable for long-term storage or burial. The Laboratory will determine the effectiveness of Diphosil™ for treating the weakly acidic to nearly neutral aqueous solutions that are typically generated by nuclear plants. The other NERI research program addresses radiation-induced corrosion as it relates to the design of next-generation reactors. Higher efficiency can be achieved by operating pressurized-water reactors at conditions well beyond the pressures and temperatures necessary for the formation of supercritical water. This work will consider the possibility of radiolytic water decomposition under these conditions.

In partnership with Northwestern University, Argonne has begun work on the Institute for Environmental Catalysis, which was developed in response to a joint call from DOE and the National Science Foundation. Pacific Northwest National Laboratory and several industrial corporations are collaborators. The institute will take advantage of Argonne's expertise in pulse radiolysis, synchrotron research (at the APS), and heterogeneous catalysis.

Argonne has proposed the following new research programs in response to DOE calls:

- *Chemistry and Nanoscience (Complex Systems).* In the major initiative Nanosciences and Nanotechnology — Center for Nanoscale Materials (Section IV.A.4), the chemical sciences goal is development of thorough knowledge of (1) molecular assembly up to the nanoscale, to understand the forces that drive aggregation and to develop experimental and theoretical methods for controlling the assembly of nanostructures; (2) controlled reactivity in hybrid nanostructures, to understand and control photochemical, catalytic, and biological reactivity in bioinorganic hybrids and mesoporous structures at the nanoscale; and (3) information transfer between nanodomains, to understand the principles by which the communication between nanoscale devices can be organized and controlled, including both the sending and accepting of information. Argonne believes that this communication will probably be best achieved through controllable delocalization and localization of the basic chemical units of charge, energy, or spin within organized arrays of nanodomains. The Laboratory's expertise in transient spectroscopies, X-ray synchrotron science, photochemistry, and theory, coupled with emerging expertise in scanning-probe microscopy, will be critical for understanding these phenomena.

- *Fundamental Research in Carbon Management and Sequestration.* Argonne's work in biochemistry will include studies of photosynthetic hydrogen production. In collaboration with the University of Chicago, the Laboratory will investigate mechanisms of oxygen sensitivity for the key hydrogenase enzyme from green algae. Work in geochemistry will focus on the fundamental chemistry of marine hydrothermal systems. In collaboration with the University of Delaware, Argonne has proposed research to investigate the longer-term fate of carbon in the middle and deep ocean. The Laboratory's research programs thus will span the two environmental fates of carbon: in the biosphere and in the geosphere.

f. Nuclear Physics

Situation

Review committees have consistently identified Argonne as one of the nation's centers of excellence in nuclear physics research. Strengths of the Argonne program include (1) low-energy heavy-ion physics, which is largely performed at the Argonne Tandem-Linac Accelerator System (ATLAS) facility (discussed in Section III.D.1.g); (2) medium-energy nuclear physics, which emphasizes the use of lepton beams (at Fermilab, TJNAF [the Thomas Jefferson National Accelerator Facility], and DESY [Deutsche Elektronen Synchrotron]) as probes into the nuclear medium; and (3) nuclear theory, which focuses on developing fundamental understanding of hadronic and nuclear structure, reactions, and dynamics.

Vision

Argonne's nuclear physics program will resolve fundamental questions concerning the characteristics and dynamics of nuclear and subnuclear degrees of freedom in nuclei and nuclear matter. This work will involve continuous development of more powerful research apparatus and methods and the use of unique research facilities at Argonne and throughout the world.

Objectives, Issues, and Strategies

Argonne's work in low-energy heavy-ion physics will take full advantage of the unique capabilities of ATLAS to explore and understand nuclei at the limits: at high excitation energies, in exotic shapes, at rapid rotation, and at extreme proton-to-neutron ratios far from stability. Producing and detecting previously unknown isotopes and studying their structures can benefit greatly from secondary (radioactive) beams, which can provide access to regions of nuclei not currently reachable with stable beams. This approach will also allow laboratory study of key reactions in astrophysics and in the creation of the elements — reactions that occur in astrophysical settings and involve short-lived nuclei. To this end, Argonne is proposing a national Rare Isotope Accelerator that will be based largely on novel superconducting accelerator technology originally developed at the Laboratory and used for ATLAS. (See Section IV.A.1.)

Argonne's work in medium-energy nuclear physics uses energetic lepton beams to increase understanding of quark and meson degrees of freedom in nuclei and the role of the quark-gluon structure of nucleons in shaping the character of nuclear forces. Laboratory researchers are playing a leading role in the research program at TJNAF, emphasizing the use of a general-purpose magnetic spectrometer constructed at the facility by the Argonne group. The Laboratory is also developing new technologies in laser atom trapping of noble gas atoms for sensitive trace isotope analyses and for tests of fundamental symmetries.

Argonne's work in nuclear theory addresses many-body aspects and the dynamics of mesons and quarks in hadrons, nuclei, and nuclear matter. Using Argonne's massively parallel IBM and SGI computer systems and other forefront computing facilities, the Laboratory has set world standards for calculations on nuclear many-body problems, work that promises answers to fundamental questions. The Argonne theory program is providing important guidance for current and future experimental programs at ATLAS, TJNAF, and Brookhaven's Relativistic Heavy Ion Collider.

g. Argonne Tandem-Linac Accelerator System

Situation

ATLAS is a DOE-designated national accelerator facility for research in nuclear physics that employs beams of low-energy heavy ions. The accelerator provides high-quality beams of all the stable elements up to the heaviest, uranium. A recently completed electron cyclotron resonance ion source has increased beam intensity by an order of magnitude. ATLAS is based on a technology developed at Argonne that employs superconducting radio frequency accelerator cavities. The ATLAS facility serves a broad community of about 300 users from more than 40 research organizations and universities.

Vision

The ATLAS facility will operate reliably and provide its national community of users with unique heavy-ion beams for research at the forefront of nuclear, atomic, and applied physics. Argonne will collaborate with U.S. industry to search for new applications of the superconducting radio frequency technology pioneered for ATLAS.

Objectives, Issues, and Strategies

The ATLAS program continues to optimize its operations and develop new linear accelerator technology to provide beams of higher intensity with excellent phase space and fast timing. Operational issues are reviewed continuously, and the facility's capabilities are frequently enhanced. Argonne will be investigating technical and research issues relating to acceleration of beams of short-lived nuclei, as a basis for proposing development of a Rare Isotope Accelerator based on ATLAS. (See Section IV.A.1.)

h. High Energy Physics

Situation

Argonne performs cutting-edge research on the physics of elementary particles and develops the instruments and accelerators needed to make that physics accessible. This work in high energy physics leverages a range of diverse resources that generally are available only at a national laboratory. Argonne's program includes five experiments at different stages of preparation or data taking, a varied theoretical program, and R&D on advanced methods of particle acceleration potentially suitable for future research facilities.

Argonne researchers perform experiments at high energy accelerator facilities in the United States and Europe. Other experiments are performed in special laboratory facilities without accelerators. In all projects, special attention is given to collaboration with university groups. This collaboration encompasses joint work on detectors and detector subsystems, as well as support for students working on theses in association with Argonne staff members.

Vision

To deepen and extend understanding of the physics of elementary particles, Argonne will provide scientific leadership and will design and assemble major components of the required experimental systems. The Laboratory will choose studies in theoretical physics for relevance to the Laboratory's experimental program or for general potential to advance understanding of interactions between elementary particles. The Laboratory will collaborate extensively with high energy physicists based at universities and will help them use Argonne's broad capabilities to maximum effectiveness.

Objectives

Major objectives of Argonne's work in high energy physics are as follows:

- Maximize the output and impact of new physics generated from the Laboratory's experiments.
- Complete the demonstration of the Argonne Wakefield Accelerator and exploit the facility for further experiments in advanced acceleration technology.
- Advance the technology of high energy physics detectors by improving existing detector devices and inventing new ones.

Issues and Strategies

High energy physics experiments are conducted in most cases by large international collaborations. Increasingly, accelerator or collider facilities are unique and are not duplicated elsewhere in the world. Accordingly, Argonne's work in high energy physics is increasingly conducted at foreign accelerators. Data taking in the ZEUS experiment at the German DESY laboratory began in 1992, and ZEUS continues to provide unique data from high energy electron-proton collisions. A major luminosity upgrade will be operational at ZEUS in 2001, permitting a new focus on extreme values of kinematic variables where rates are low. Currently under way is fabrication work on a detector for the Large Hadron Collider (LHC) being planned at the CERN Laboratory in Switzerland. Argonne researchers have established leadership roles in the ATLAS (A Toroidal LHC ApparatuS) detector, one of two major detectors planned for the LHC (and unrelated to the ATLAS facility located at Argonne). The U.S. government has a formal agreement with CERN that details the scope of U.S. participation in the LHC and the level of funding to be provided by DOE and the National Science Foundation.

Argonne will be carefully considering expansions or new directions for many of its programs in high energy physics, in order to preserve their effectiveness in the next decade. Argonne researchers participating in the underground Soudan 2 experiment have formed a new collaboration, “MINOS,” whose work toward a long-baseline study of neutrino oscillation, employing a neutrino beam from the new Fermilab main injector, is entering the construction phase. The “far” detector is to be underground, adjacent to the current Soudan 2 detector in Minnesota. A major upgrade of the CDF (Collider Detector at Fermilab) that is being completed will begin taking data with the upgraded Fermilab Tevatron in 2001. Argonne’s Wakefield Accelerator R&D program is now preparing for the second phase of its demonstration program; in order to explore ways of using this new accelerator technology in future experimental facilities, the Laboratory is discussing possible collaborations and alliances with researchers at other institutions.

Argonne is making many contributions to the MINOS long-baseline neutrino oscillation experiment, which focuses on unsolved questions about neutrinos. The Laboratory has primary responsibility in the United States for installation of electronics and the far detector and also has major involvement in the development and eventual fabrication of the scintillator planes. Final design and prototyping will continue through FY 2000, while cavern excavation in Minnesota begins. Construction of the detector will begin in FY 2001. First data are expected early in FY 2003, with half the detector operational. The remaining half of the detector will be completed in FY 2004.

The ATLAS detector at the CERN Laboratory in Europe is designed to solve the fundamental puzzle concerning the mechanism of electroweak symmetry breaking and the origin of mass. Calorimeter fabrication began in FY 1999 and must be completed by late FY 2002, when installation begins at CERN. Argonne is currently contributing to the design and prototyping of the trigger for ATLAS. System components will be built, tested, and commissioned during the coming five years. Development of the computing system for the ATLAS detector began as a new task in FY 2000. In collaboration with other U.S. and foreign ATLAS institutions, Argonne will take the lead role in developing core data management software, as well as calorimeter-specific software.

The proposed ATLAS software task is discussed below as a programmatic initiative.

Initiative: ATLAS Detector Software Development

Provision of computing systems to support U.S. participation in the ATLAS detector at CERN’s LHC was not addressed in the original combined LHC project agreement. This task, now being organized, will include the provision of computing, storage, and networking facilities in the United States to support simulation and analysis of ATLAS data by U.S. researchers. This task will also include software development by U.S. collaborators that will contribute to the overall ATLAS software system. Argonne, in cooperation with the University of Chicago, is seeking to lead the development of a major part of the software for which the United States has responsibility. The detailed work plan, which is under development, will include an early pilot project aimed at using test beam data from the tile calorimeter, on which groups from both Argonne and the University of Chicago are working. In addition, U.S. groups will select key pieces of the core software for ATLAS to be developed as U.S. responsibilities.

Resources required for work on ATLAS software are summarized in Table III.2. Funding is sought from the High Energy Physics Program (KA-04).

Table III.2 ATLAS Detector Software Development ($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	0.4	1.0	1.5	2.0	2.0	2.0	2.0
Capital Equipment	-	0.2	0.2	0.4	0.6	0.6	0.2
Construction	-	-	-	-	-	-	-
Total	0.4	1.2	1.7	2.4	2.6	2.6	2.2
Direct Personnel	2.0	5.0	7.0	10.0	10.0	10.0	10.0

i. Mathematics, Computing, and Information Sciences

Situation

In the coming decade, computational modeling and simulation promise to change fundamentally the way scientists attack complex problems. If Argonne researchers are to contribute significantly to this revolution, they must have access to state-of-the-art computing resources, and a new generation of modeling software capable of exploiting these resources must be developed.

The Laboratory currently operates a Center for Computational Science and Technology (CCST) that was established to meet the computing needs of the DOE Grand Challenge Applications program (URL: www.mcs.anl.gov/). The CCST is officially scheduled to close with the completion of that program in the year 2000, but Argonne must continue to offer world-class computer resources to its scientists and engineers.

Advanced scientific simulation also requires a strong scientific computing software infrastructure. Argonne's extensive software development program focuses on emerging technologies that will be fundamentally important to meeting the challenge of complex applications during the next decade. These technologies include object-oriented design and programming, new communication paradigms for the interoperability of collaborative applications, and novel interfaces that enable applications programmers to use and combine software and components from different libraries easily. Working in partnership with other national laboratories, with universities, and with industry, the Laboratory strives to bring these emerging tools into wide use in real applications.

Vision and Goals

Computing science contributions at Argonne over the next five years will center on scalable computational resources, expertise in strategic applications areas, solving major scientific and engineering problems, remote sharing of instrumentation and immersive visualization facilities, and collaborative teams of computational and computer scientists.

Key to this vision are world-class supercomputing and networking resources, complemented by world-class algorithms, tools, and software. The Laboratory will explore diverse avenues to high performance, including scalable-cluster technology, distributed supercomputers, and teraops computer systems. The goal is to offer terascale computing, with an order-of-magnitude increase in bandwidth and a decrease in latency.

Argonne researchers also will make seminal contributions to the software base for the next generation of problem-solving environments by addressing a wide range of challenges related to collaborative and distributed computing. Emphasis will be on open-source tools that make it easy for scientists to obtain codes, methods, and libraries and to work together in tackling large-scale scientific problems. In addition, Argonne will participate in large-scale joint ventures — such as the National Computational Science Alliance in the Partnerships for Advanced Computational Infrastructure — by researching, developing, and validating the technology needed to support applications scientists.

Objectives

Argonne has established the following specific objectives for its mathematics, computing, and information sciences program:

- Encourage Laboratory-wide strategic computational science applications that advance the frontiers of science in such areas as computational chemistry, nanoscience, bioinformatics, combustion, and tomographic and crystallographic imaging.

- Contribute importantly to the nation's enabling computing technologies by developing the software tools, distributed computing, visualization, and numerical libraries needed to solve the most challenging scientific problems.
- Develop computational methods that can make better predictions in critical policy areas, such as climate modeling.
- Integrate efforts in advanced computation (including computer science, mathematics, and computational science) with experimental and theoretical research.
- Explore new technologies by anticipating needs and advancing the state of the art of large-scale computing in ways that make researchers more productive.

Issues and Strategies

Argonne researchers in mathematics and computer science continue to be at the forefront of scientific computing, leading efforts to develop new paradigms and technologies. One important area of work is distributed computing systems, where coupling workstations with parallel computers, large databases, virtual-reality devices, and other resources promises tremendous advances in scientific problem solving. The Laboratory's aggressive pursuit of ways to enable distributed collaborative science applications includes (1) the Distributed Systems Laboratory, which is dedicated to making distributed systems usable and broadly accessible, and (2) the Futures Laboratory, which is developing shared-virtual-space technology and a national teleimmersion test bed. Other projects explore a broad range of R&D issues at the intersection of high-performance computing and networking (including resource scheduling, data access, and security technologies).

Funding is a major issue. Recent federal reports seem more positive about support for basic science in general (e.g., in structural genomics and materials science) and about information technology research in particular, but DOE funding for the computing sciences actually declined in FY 2000. Potential benefits from programs that were once strong and growing may be lost if this trend is not reversed. Fundamental knowledge and appreciation of the long-standing, major contributions made by the DOE laboratories to computing science appear to be lacking. To address this issue, Argonne has spearheaded efforts to expand computational science across the DOE science laboratories. Recent efforts to establish an advanced computing modeling and simulation program seem to be gaining sufficient support to become a focal point for funding decisions in FY 2001. Argonne seeks to make major contributions to this program as an enabling technology center, with responsibility for researching, developing, and deploying a new generation of software to enable simulations of complex systems. See discussion of the major initiative Enabling Technologies Center for Advanced Computational Modeling in Section IV.A.3.

One promising avenue for advancing large-scale computing is Argonne's partnership with the University of Chicago to establish the Computation Institute for interdisciplinary research in computational science. The Computation Institute will help Argonne to leverage both research activities and funding from other agencies.

Progress in computer and communications technologies has set the stage for major advances in scientific problem solving. Argonne sees a tremendous opportunity to contribute to this advancement, particularly with adequate investments in the hardware and the software development required for computational modeling and simulation.

j. Intense Pulsed Neutron Source

Situation

The Intense Pulsed Neutron Source (IPNS) has operated as a national user facility since its commissioning in 1981. Among DOE neutron sources, it has one of the largest user programs: approximately 350 experiments per year, with over 200 scientists conducting at least one experiment during the year. The IPNS is DOE's most cost-effective neutron source. The high scientific productivity and cost-effectiveness of the IPNS have been noted frequently by national and international committees. The IPNS currently has 13 neutron-scattering instruments and facilities for studies of radiation effects. Additional funding provided by DOE's Scientific Facilities Initiative has allowed operations to increase substantially over the 18 weeks supported in FY 1995. This increase is in accord with earlier recommendations of the Panel on Neutron Sources of the Basic Energy Sciences Advisory Committee (BESAC). The IPNS operated for 25 weeks in FY 1999, and 26 weeks are scheduled in FY 2000.

Vision

The IPNS will function as a reliable and accessible user facility for neutron-scattering research and as a successful developer of targets, moderators, and state-of-the-art neutron-scattering instrumentation. The staff will help qualified users conduct world-class research on condensed matter, addressing a wide range of questions important to both science and technology. Through the IPNS Enhancement initiative, the IPNS will maintain leading-edge capabilities in neutron scattering.

Objectives

Major objectives for the IPNS are as follows:

• Operate the IPNS in a highly reliable manner, with availability exceeding 95%, and provide effective scientific assistance to qualified users.

• Operate 30 weeks per year, with sufficient staff to support users fully.

• Develop new technologies for targets, moderators, and instrumentation that will increase the capabilities of pulsed spallation neutron sources.

• Through the IPNS Enhancement initiative, significantly improve instruments, target/moderators, and accelerator systems to bring scattering capabilities for many IPNS instruments up to the level of the ISIS facility in the United Kingdom.

Issues and Strategies

The IPNS has historically been severely oversubscribed, understaffed, and underutilized. The additional $4 million in IPNS operating funds included in DOE's Scientific Facilities Initiative now allows approximately 25 weeks of operation per year, with a full complement of instruments serving users.

On the basis of its broad experience in accelerator-based neutron sources, Argonne plans to continue conducting R&D in support of accelerators, targets, moderators, and instruments for advanced spallation neutron sources. IPNS personnel have been assigned the lead role for the design and construction of neutron-scattering instruments for the Spallation Neutron Source (SNS). Testing of prototypes of these instruments at the IPNS will broaden the SNS user community.

Also at the SNS, Argonne has been given the leadership role in the development and operation of a second target station optimized for long-wavelength neutron scattering. The National Science Foundation has indicated interest in supporting development of such a target station, and a proposal to develop a conceptual design report was submitted. The first year of that three-year proposal was funded. See Section IV.A.5 for discussion of the major initiative SNS Long-Wavelength Target Station.

Initiative: IPNS Enhancement

Argonne's IPNS continues to host the most cost-effective user program among DOE's neutron sources, a user program comparable to the best in the world. In FY 1999 more than 200 scientists came to the IPNS to perform approximately 330 experiments. Additional funds provided by the Scientific Facilities Initiative, now part of the IPNS funding base, have permitted significant increases in support for users and a doubling of the amount of instrument time available to users.

Long-term plans for the IPNS include — in addition to continuing operation as a highly productive scientific user facility — development of new instruments for use at the IPNS and at the SNS, which is currently being designed at Oak Ridge National Laboratory (ORNL). Under the

IPNS Enhancement initiative, Argonne proposes to improve existing instruments significantly (increasing data rates by factors ranging from 2 to 32) and to increase the number of weeks of operation to enable an expanded user community to gain experience at a pulsed source in preparation for using the SNS. In addition, the initiative will support operating time for testing new equipment concepts, components, and prototypes for SNS instruments. These additional operations and scientific capabilities were detailed in a plan presented to the February 14, 2000, meeting of the BESAC Subpanel on Neutron Scattering. These Argonne plans were then included in the subpanel recommendations approved by BESAC on February 28, 2000.

Work on equipment under the IPNS Enhancement initiative falls into three categories — (1) replacement target, (2) accelerator upgrades and spare parts, and (3) instrument enhancements — as follows:

1. The neutron-producing target at the IPNS lasts approximately four years and costs $1 million. Each year, $250,000 is requested for this ongoing expense.

2. Many parts of the IPNS accelerator system are old (some over 40 years) and need upgrading. Moreover, in order to continue operating at a high reliability of 95%, more spare parts are needed. Both accelerator upgrades and spare parts availability have suffered from a lack of equipment funds in recent years. An additional $1 million annually is requested.

3. The performance of all IPNS instruments can be increased significantly through various enhancements, such as more detectors, better data acquisition systems, and new ancillary equipment. These enhancements, which have been planned in detail for the next four years, will improve data rates by factors as great as 32, allowing many IPNS instruments to perform as well as those at the world's best pulsed neutron source, ISIS in the United Kingdom. An additional $1 million annually is requested.

On the basis of their long experience and demonstrated capabilities in developing instrumentation, IPNS personnel have been assigned the lead role in plans for developing SNS instrumentation. Argonne is responsible for designing and constructing instruments for the SNS, and many of the instruments and instrument components will be developed as prototypes at Argonne, tested on IPNS beamlines, and later constructed at IPNS for delivery to SNS. The SNS was approved for construction as a line item in the FY 1999 federal budget.

The process of building and using prototype instruments at the IPNS is expected to broaden and strengthen the community of scientific and technical users for the SNS. IPNS held workshops with potential users of neutron scattering from a broad technical community, including such fields as structural biology, materials engineering, and geoscience, in addition to the more traditional fields of condensed-matter physics, materials science, and chemistry. These scientific workshops aim to identify and foster valuable applications for neutron scattering and to define specifications for SNS instrumentation. The first 5 (of 12) scientists being hired by ORNL to work on instrument development at Argonne began work in 1998.

Resources required for the IPNS Enhancement initiative are summarized in Table III.3. Funding will be sought from DOE's Office of Basic Energy Sciences (KC-02).

Table III.3 IPNS Enhancement
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	-	1.9	2.0	2.1	2.2	2.3	2.3
Capital Equipment	-	2.4	2.4	2.5	2.6	2.7	2.8
Construction	-	-	-	-	-	-	-
Total	-	4.3	4.4	4.6	4.8	5.0	5.1
Direct Personnel	-	17.0	17.0	17.0	17.0	17.0	17.0

k. Biosciences

Situation

The sequencing of the human genome is approaching completion, and dozens of other genome sequences are either completed or in process. Over the next few years this unprecedented flood of nucleotide sequence data will continue to grow. With these accomplishments, biology has reached a turning point at which a complete enumeration of the molecules making up an organism is within reach. The challenge now is to use this information to construct a detailed, coherent, complete view of living organisms and to use this view to develop powerful methods for manipulating and engineering biomolecular systems and predicting their responses to environmental stimuli. The key to such detailed control of biomolecular systems lies in a complete mapping of the activities of the molecular machines that interact and cooperate to perform all cellular processes. The information required to characterize these processes is embedded in the spatiotemporal distribution of gene products and metabolites across multiple length scales.

In coming years, progress in the biological sciences will depend increasingly on interdisciplinary interactions with computational, physical, chemical, and materials scientists. As implementation of high-throughput techniques for biochemical and biophysical characterization of biomolecular systems produces huge volumes of data, cataloging and preserving those data will be a significant challenge in database design and maintenance. In the longer run, integrating those data into a complete view of cellular and, ultimately, organismal behavior will require novel approaches to simulations of complex systems. In the 21st century, computation will come to dominate the biological sciences.

Vision

Argonne will move toward a leadership position in postgenomic biology by creating a model program for integrative analysis of biomolecular networks and cellular systems. The Laboratory will take advantage of its strong programs in the physical, chemical, materials, and computational sciences to build, along with biosciences, a uniquely interdisciplinary program for postgenome biology. Argonne's superb environment for interdisciplinary research will be fully exploited. Experimental facilities at the APS and world-class computational resources will be integral parts of a comprehensive program for structural and functional characterization of biomolecular systems — a program that will be centered around the Laboratory's quickly growing effort in structural genomics. Revolutionary approaches to currently intractable problems will be explored in collaboration with Argonne physicists, chemists, and engineers. Programs in bioinformatics, nanobiotechnology, photosynthesis, and combinatorial biology will engage scientists at both the Laboratory and the University of Chicago. The goal is a program of great breadth and depth that focuses on complete characterization of complex biomolecular systems and predicts from first principles the responses of biological systems to complex external stimuli.

Objectives

Argonne's program for the comprehensive analysis of complex biomolecular systems will grow around the current structural genomics program by taking advantage of both resources supporting the current program and other resources at the APS. The program will reach out to develop close ties with other programs at the Laboratory and the University of Chicago and will initiate cross-disciplinary interactions aimed at creating revolutionary approaches to currently intractable problems.

Argonne's major objectives in biosciences are as follows:

- *Structural Genomics.* Develop a scientific program aimed at deepening understanding of protein structure and function — a program centered on current efforts to characterize to atomic resolution the three-dimensional structure of all gene products.
- *High-Throughput Crystallization.* Develop robotics capabilities for the rapid and efficient production of diffraction-grade crystals of biological macromolecules, thereby eliminating the most severe bottleneck in the Laboratory's structural genomics work.
- *Bioinformatics.* Develop a robust program of scientific database development for the structural and functional analysis of gene product activities, based on analyses of sequence, structure, and function.
- *Computational Biology.* Develop a program for simulating networks of

biomolecules where the simulations initially involve cellular subsystems, then later involve whole cells, and where the goal is predicting cellular response to complex external stimuli.

• *Revolutionary Approaches to Membrane Protein Crystallization.* The 30% of proteins that are integral components of cellular membranes cannot be investigated by using the techniques that are successful in crystallizing other proteins. In collaboration with physical and chemical scientists, Argonne will explore revolutionary approaches to the crystallization and biochemical analysis of these proteins.

• *Functional Genomics.* Argonne's current use of robotics for high-throughput expression of proteins will provide milligram quantities of hundreds of proteins for functional analysis. In parallel with crystallization efforts, these proteins will be analyzed by using functional proteomics, combinatorics, and small-angle X-ray diffraction. The robotics expertise of Laboratory scientists will be exploited to develop techniques for high-throughput biochemical and biophysical analyses.

• *Small-Angle X-ray Scattering.* The structure of gene products that cannot be crystallized will be analyzed by using small-angle X-ray diffraction from aqueous solution. Methods for predicting protein structure from solution scattering will be developed in coordination with bioinformatics analysis of existing protein structure databases.

• *Program for Combinatorial Biology.* A comprehensive, multitasked program in combinatorial biology will be developed to take advantage of the huge potential for molecular engineering and analysis of molecular recognition processes. This program will use combinatorial libraries of proteins and peptides displayed on the surfaces of viruses and bacteria and will screen these libraries for desired functionalities.

• *Program in Nanobiotechnology.* Argonne materials scientists and biologists will cooperate to develop a major new program in nanobiotechnology that will explore the creation of bio-inspired nanostructures and bio-compatible materials and the structural analysis of complex biological materials.

• *Integrated Approach to Photosynthetic Systems.* Taking advantage of existing expertise in photosynthesis and electron transfer systems among Laboratory biologist and chemists, Argonne's integrated approach to the study of biomolecular photosynthetic systems will be further integrated with an effort to engineer novel molecular solar energy systems. A computational approach to the structural genomics of photosynthetic and electron transfer systems will be used to establish common structural motifs among photosynthetic proteins and to aid in the design of novel systems.

• *Whole-Cell Structure.* Argonne materials scientists and biologists will collaborate to establish electron microscopy and computational facilities for whole-cell electron tomography of living systems. Gene product distribution throughout whole cells will be tracked by using tags with well-defined electron absorption characteristics. The goal is to establish the spatial and temporal distribution of individual gene products throughout the cell cycle and as affected by environmental signals.

Issues and Strategies

Argonne is uniquely positioned to take advantage of the extraordinary opportunities developing in postgenomic biology. Through multidisciplinary collaborations among scientists across the Laboratory and at the University of Chicago, Argonne will seek leadership in several well-defined areas of the biological sciences and will explore revolutionary approaches to a number of currently intractable problems in structural and cellular biology.

The core of Argonne's current efforts in biosciences is work in structural genomics to establish high-throughput macromolecular crystallography and its use for enumerating all existing protein structural motifs. This work has motivated initiatives in high-throughput crystallization of macromolecules and high-throughput expression of proteins in bacterial hosts. Based on the Laboratory's existing robotics expertise, these initiatives will provide a further base for developing robotics for rapid biochemical and biophysical assays of protein structure and function. Argonne's existing structural genomics efforts are tightly focused on crystallographic studies, and augmentation in the directions indicated is a priority.

In general, development of new interdisciplinary interactions across the Laboratory and with the University of Chicago will drive Argonne's planned initiatives in the biosciences, where DOE and the National Institutes of Health (NIH) will be major funding sources. In addition, important funding from the state of Illinois is being sought to enhance the planned program in high-throughput crystallization. A key complementary strategy is development of cooperative agreements with biotechnology companies for joint development of novel methodologies.

Major Argonne initiatives in the biosciences will focus on four parallel and complementary efforts in macromolecular crystallography that are being pursued as close partnerships. (1) The capabilities of the existing DOE-funded Structural Biology Center are being enhanced significantly through support from NIH. The Midwest Center for Structural Genomics will receive from NIH approximately $5 million per year for development of high-throughput macromolecular crystallography. (2) In partnership with this effort, Argonne is also working with NIH to develop a second APS sector for macromolecular crystallography. (See Section S1.C.4 for discussion of these two NIH-supported efforts.) (3) To facilitate this work, a laboratory complex for biostructure research will be constructed at the APS with joint DOE and NIH funding (see Section IV.A.7). (4) Argonne is also working with the state of Illinois on plans to construct an Accelerated Protein Crystallization Facility at the APS, which is to include development of an additional APS sector for structural genomics and macromolecular crystallography. Close partnerships among these four efforts will enable significant economies of scale, facilitating rapid improvement in our understanding of protein structure and function.

Around these significant initiatives in structural genomics and crystallography, Argonne is building a major program in functional genomics. This effort will take advantage of robotics facilities for protein cloning, expression, and purification that are being developed for structural genomics. The robotics facilities will be able to provide the significant quantities of protein required for detailed functional characterization. The functional genomics initiative will further include a significant buildup of bioinformatics capabilities, in support of both structural genomics and high-throughput functional analysis. The major initiative High-Throughput Systems for Biomolecular Research (see Section IV.A.2) will have major benefits, as the scientific focus of biology shifts to analysis of whole systems and to computational integration of all available biomolecular information.

l. Biotechnology

Situation

Biotechnology research at Argonne is a multidisciplinary, crosscutting effort that integrates diverse expertise and technologies through molecular studies using unique research facilities. The focus is development and adaptation of technologies that can support new applications or innovative approaches to solving old problems. Applications range from genetic engineering to ice slurries to separation and purification using advanced membranes.

Vision

Argonne's biotechnology research — basic and applied — will increase knowledge in DOE mission areas at the interface with biotechnology on many fronts. Based on the resulting new applications in biotechnology and biomedicine, millions of dollars in economic value will be created through the spin-off and growth of new companies.

Objectives

In the areas of health, industry, and the environment, key objectives include the following:

- Advance the development and use of biological microchips (biochips) to speed the identification of mutations in human genes and to allow identification of viruses, bacteria, and bacterial toxins. Develop, expand, and apply integrated, automated biochip technology in scientific research and in applications for medical diagnostics, pharmaceuticals, disease treatment, environmental restoration, and agricultural innovation.

- Study the ability of biochemicals to control leukemia and other cellular malignancies. To screen for new cancer drugs, use specific enzymes as guides to block or activate certain biochemical sites. Study cellular replication and differentiation and programmed cell death.

- In biomedical engineering, develop better emergency resuscitation technologies, apply artificial intelligence to medical diagnostics, and develop new prosthetic materials and coatings.

- Through partnerships with industry, promote industrial processes based on environmentally friendly "green" solvents, support an emerging biobased chemical industry, and develop biocatalytic systems for producing chemicals economically from renewable resources.

- Advance environmental remediation by developing and testing additional novel technologies to monitor, remove, detoxify, and recover — from pipelines, soils, groundwater, and aqueous waste streams — heavy metals, unwanted organic compounds, undesirable bacteria, and other matter.

Strategies for Health

Biochips and DNA. Through a $19 million CRADA over five years with Motorola, Inc., and Packard BioScience Company, Argonne is working on advanced biochips and related analytical technologies to permit faster and more efficient detection of mutations in genetic information encoded in deoxyribonucleic acid (DNA). Another collaborative project with Northwestern University, for the Defense Advanced Research Projects Agency, is developing an analysis tool to identify microorganisms and toxins in the field. In an emerging project with Russian sanatoriums and with public health centers in the Chicago area, researchers are developing ways to use biochips to identify and treat virulent, multidrug-resistant tuberculosis strains.

Cancer and Biochemicals. Argonne seeks to examine the molecular events that govern cellular replication, cellular differentiation, and programmed cell death in normal and tumor cells. Results could guide the development of highly specific pharmaceuticals.

Emergency Resuscitation. A joint research program with the University of Chicago seeks to develop devices and procedures to cool the heart and brain during cardiac arrest or stroke, to monitor oxidant stress during sudden cardiac arrest, and to enhance electrocardiogram traces to predict potential for recovery. A primary goal is lengthening the time prior to emergency care before irreversible damage occurs.

Strategies for Industry

"*Green*" *Solvents*. Through an industry-government initiative, Argonne developed a novel membrane-based process for producing environmentally benign ethyl lactate at sufficiently low cost so it can replace toxic solvents. The technology is licensed to Vertec Solvents. Now, through a collaboration with the University of California at Davis, the Laboratory is investigating the conversion of cellulosics to mixed sugars that are subsequently converted to lactate esters.

Biobased Chemicals. Argonne is merging basic and applied research to create cost-competitive methods of producing environmentally advantageous chemicals from agricultural materials. Success depends on developing novel techniques for biocatalysis and separations. Through collaborative research in biocatalytic operating systems (biomimetic membrane transport), the Laboratory is seeking to develop (1) ways to use corn as a feedstock to produce chemicals such as vitamin C, ethyl lactate, and succinic acid and (2) chemical production systems having reduced production costs and increased specificity.

Strategies for the Environment

Microbial Corrosion. With Southern California Gas, Argonne is investigating more environmentally acceptable on-line methods of detecting and treating corrosion influenced by bacteria in pipelines and recovery wells.

Phytoremediation. Argonne researchers have demonstrated at the laboratory and greenhouse scales that higher plants can provide effective, low-cost phytoremediation, which is the engineered application of plants to remove environmental contaminants, contain them, or render them harmless. The Laboratory is now pursuing field demonstrations of bioremediation technologies and biobased monitoring methods aimed at helping DOE tend to the contaminated sites under its long-term care.

Surfactant Bioremediation. Argonne is experimenting with specially designed foams to increase the effectiveness of *in situ* bioremediation in cleaning up soil and groundwater contaminated by nonaqueous-phase organic liquids.

Photocatalysts for Waste. Argonne is developing and testing unique photocatalysts for the removal, detoxification, and recovery of heavy metals (such as lead, cadmium, chromium, copper, mercury, and arsenic) from aqueous waste streams, with simultaneous destruction of organic compounds (such as carbon tetrachloride and trichloroethylene). This technology could benefit both DOE and industry.

Initiative: Biochips and DNA

Cellular mutations and genetic information are encoded in DNA and packaged in chromosomes. Each chromosome contains thousands of individual genes, most of which have not yet been identified. Roughly 100,000 genes constitute a complete set of 46 chromosomes in humans; this genome serves as nature's blueprint for every protein in a person's body. Scientists at Argonne and at the Engelhardt Institute of Molecular Biology in Moscow, Russia, are collaborating to develop a biochip that accelerates the decoding of DNA, and they are investigating the following expanding array of applications:

- DNA sequence analysis and proofreading
- Analysis of changes (mutations) in the genetic makeup
- Analysis of population differences in genetic coding (polymorphism)
- Identification of bacteria and viruses and their products
- Analysis of gene expression as it relates to health care, disease prevention, and drug treatment
- Advanced medical diagnostics and treatment monitoring
- Detection of genetically engineered biothreat agents

The Argonne biochip incorporates thousands of tiny gel pads on the glass surface of a small slide. Each gel pad contains a bit of DNA, protein, or some other chemical or biological compound of interest. The fact that a given bit of DNA can recognize a complementary piece allows long stretches of nucleic acids to be read piece by piece. Once thousands of known strands of DNA or other organic bits are fixed in place on slides, then robots and other automated equipment can use the slides as templates to test and decode unknown samples. It becomes possible, in a single test, to decode the sequence of an unknown DNA strand or to identify an unknown organic macromolecule or organism.

Generic biochips are useful in reading unknown sequences or proofreading sequences obtained by alternative methods. They can also be used to detect small changes in the genetic makeup of organisms such as viruses. This capability may permit the testing of vaccines to ensure that the attenuated viruses intended to induce an immune response have not mutated into a deadly new strain. *Customized biochips* can be used to study gene polymorphism (the slight differences in certain genes across a population). For example, relatively small changes in a human leukocyte gene have been associated with susceptibility to disorders such as malaria and multiple sclerosis, allergy, and other autoimmune diseases. To analyze for this gene, a customized chip containing approximately 70 oligonucleotides of various lengths is used.

Bacterial identification employs a custom-designed biochip containing known stretches of DNA from certain regions of the bacterial genome. When nucleic acids are isolated from a test bacterium and reacted with this chip, positive signals occur only in certain of the gel pads. The resulting pattern allows identification of the test bacterium in a way analogous to human fingerprinting.

The full promise of Argonne's biochips extends far beyond simple identification of species, analysis of gene expression, and medical diagnosis. For example, it is conceivable that genetic engineering could, accidentally or maliciously, turn harmless microbes into deadly bacteria by introducing lethal genes into otherwise harmless hosts. In preparation for such contingencies, it is important to be able to detect the genetically transformed bacteria and identify the particular disease-causing agent. Argonne is working on a biochip for field analysis that can simultaneously detect and distinguish a vast number of biothreat agents, including bacteria, viruses, fungi, and toxins.

Resources required for this initiative are summarized in Table III.4. The funding increase shown for FY 2001 is anticipated from a combination of DOE-BER (KP), other federal agencies, and the private sector.

Table III.4 Biochips and DNA
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	1.7	2.5	2.8	2.8	2.8	2.8	2.8
Capital Equipment	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-
Total	1.7	2.5	2.8	2.8	2.8	2.8	2.8
Direct Personnel	20.0	20.0	20.0	20.0	20.0	20.0	20.0

Initiative: Biochips for Fast Diagnostics and Discrimination of Multidrug-Resistant Tuberculosis Strains

Tuberculosis, once the leading cause of death in the United States, currently kills more than three million people worldwide each year. Tuberculosis is responsible for more deaths than any other single infectious disease (including AIDS and malaria), and it is the biggest killer of HIV-positive individuals. A third of the world's population is infected; about 15 million actively exhibit the disease. Recent outbreaks have centered in areas where population density is high and the cost of full treatment is prohibitive. If initial treatment is shortened, inconsistent, or inappropriate, surviving bacteria reproduce and pass on their resistance. The resulting drug-resistant tuberculosis strains become increasingly difficult to treat.

Biochip technology promises to help stem the global resurgence of tuberculosis. Developed by Argonne and the Engelhardt Institute of Molecular Biology of the Russian Academy of Sciences, this technology is expected to help health organizations deal with new drug-resistant tuberculosis strains by quickly distinguishing among the strains and thus indicating the appropriate antibiotic to use.

Standard testing for tuberculosis requires a sequence of tests: first, a skin test to determine any previous exposure; second, a chest X-ray to determine whether tuberculosis has damaged lung tissue; and finally a throat culture to determine whether the tuberculosis bacterium is still growing and to what antibiotics it is resistant. Unfortunately, results from a throat culture alone can take more than a month. Automated biochip technology promises to make all the required information available within a couple of hours, at low cost.

Argonne will use biochip technology to distinguish among different strains of tuberculosis by using harmless segments of genetic material from the bacteria. This work will serve as a prototype for similar evaluations of other bacterial and viral diseases and for effective procedures in international clinical trials.

Particular tasks to be undertaken include the following:

- Immobilize sequence-specific oligonucleotides that correspond to mutations of the bacterium exhibiting resistance to particular antibiotics.

- Evaluate the enhanced accuracy achievable by means of contiguous-stacking hybridization.
- Test more accurate and more expensive single-base extension assays on the biochip; analyze for drug resistance.
- Combine PCR (polymerase chain reaction) amplification and hybridization procedures on a single biochip, to make inexpensive the mass analysis of hundreds of mutations responsible for drug resistance.
- Develop a simplified version of the fluorescence microscope used to monitor the biochips that is sufficiently inexpensive for ordinary clinics.

Collaborators in this work include eight Russian institutes and sanatoriums, the Illinois Department of Public Health, the Chicago Division of Communicable Disease, and the Cook County Hospital in Chicago.

Initiative: Biobased Chemicals

In August 1999 the White House issued Executive Order 13134, which aims at promoting the development of biobased products and bioenergy. The associated DOE initiative in biobased chemicals could foster a midwestern chemical industry that uses agricultural feedstocks to produce environmentally advantageous, cost-competitive chemicals. Developing the technological underpinnings for such an industry will require integrating biotechnology with nanosciences, informatics, engineering, agriculture, and robotics. To this end, Argonne is strengthening its capabilities in biocatalytic and downstream processing, development of automated robotic systems for gene cloning and expression, application of bioinformatics programs (such as WIT and PUMA), and application of the unique structural biology resources at the APS.

In the fledgling research area of biobased chemicals, Argonne is already a leader. Current projects range from using corn as a feedstock to produce chemicals (“green” solvents, vitamin C, and succinic acid) to development of advanced membrane processes for lower-cost downstream processing and purification. The Laboratory is applying nanoscience and structural biology to address fundamental issues in biocatalysis and has already won several awards for work on biobased chemicals, including the President’s Green Chemistry Award, the Discover Award for Technology Innovation, the *R&D* 100 Award, the Thiele Award, and the Federal Laboratory Consortium Technology Transfer Award. An Argonne project is one of three finalists (out of 1,000 projects) for designation as “the project of the year” for DOE’s Office of Industrial Technologies.

Technologies and partnering arrangements developed at Argonne have already created start-up companies in biobased chemicals. In addition, an Argonne-Industry Partnership for Biobased Chemicals is being established regionally with major companies, universities, and associations. The Laboratory focuses on fundamental limitations in biocatalysis and processing as they affect product cost, and it emphasizes near-term opportunities and collaboration with small and midsized companies.

Resources required for this initiative are summarized in Table III.5. Funding is sought from DOE-Energy Efficiency, DOE-Environmental Management, DOE-Science, and DOE-Fossil Energy. Support is also anticipated from other federal agencies and industrial partners.

Table III.5 Biobased Chemicals
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	5.0	7.8	8.7	8.7	8.7	8.7	8.7
Capital Equipment	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-
Total	5.0	7.8	8.7	8.7	8.7	8.7	8.7
Direct Personnel	20.0	30.0	33.0	33.0	33.0	33.0	33.0

m. Environmental Research

Situation

Environmental issues continue to be a leading national concern, reflecting population growth, economic development, and the environmental legacy of past activities and practices. The focus is shifting from effluent control technologies and associated regulation toward waste and resource management, site remediation and long-term stewardship, facility decontamination, and global environmental issues. Basic and applied research leading to more cost-effective environmental technologies and practices is increasingly important. Moreover, new technology and information — such as geographic information systems, computer imaging, and satellite survey data — have created opportunities to address hitherto intractable environmental problems.

Vision

Argonne will continue to provide national and international leadership in key areas of environmental research by developing innovative and cost-effective solutions to high-priority environmental problems, such as carbon cycling and carbon sequestration; climate change and air quality; biogeochemical cycling; and improved site characterization and remediation. Laboratory researchers of recognized professional standing, complemented by state-of-the-art facilities and instruments, will address problems at the frontiers of environmental science that are technically challenging, broadly relevant, and unlikely to be resolved in a timely fashion through private-sector R&D alone.

Objectives

Central objectives of environmental research at Argonne are as follows:

- Expand the Atmospheric Boundary Layer Experiments site as a facility generating data required for research on climate change, including the exchange of carbon and water between the atmosphere and terrestrial ecosystems.
- Continue to develop atmospheric chemistry and environmental chemistry research capabilities, to provide the advanced information on the atmospheric environment required for long-range energy planning.
- Develop synchrotron-based techniques for molecular environmental science, based on the high-brilliance X-rays of the APS.
- Develop new methods for identifying, characterizing, remediating, restoring, and monitoring contaminated environments.

Issues and Strategies

Argonne has significant core capabilities in bioprocessing; ecology; modeling and measuring environmental pathways; atmospheric physics and chemistry; developing “clean” technologies; control and remediation technologies; inorganic and isotope geochemistry; and development of decision models for rapid, cost-effective remediation of DOE sites. This foundation provides important opportunities for fruitful integration of applied environmental studies with fundamental capabilities in physics, chemistry, and biology.

Cost-effective resolution of the important environmental issues facing the nation and the world generally requires the integrated application of multiple scientific disciplines. Argonne believes that the future of environmental research at the national laboratories lies in increased emphasis on basic and applied research conducted by multidisciplinary teams able to exploit fully the major research facilities and other unique capabilities of the laboratories. Better solutions to environmental problems can be achieved by both expanding the knowledge base and better applying what is already known.

In the area of atmospheric science, Argonne is building on its existing capabilities in atmospheric science, remote sensing, advanced computation, information processing, and important observational efforts in climate change, atmospheric chemistry, carbon cycling, and hydrology. Facilities are managed with the overall objective of making available to all qualified users continuous, long-term observations from state-of-the-art instruments distributed over a large area in a meteorologically important region of the country and thereby to create a key national asset for progress in atmospheric and hydrospheric research.

A recent reorganization of the DOE-BER Atmospheric Radiation Measurement (ARM) Program defined three separately funded tasks. Beginning on June 1, 2000, Argonne assumed responsibility for operations and oversight for all three ARM Cloud and Radiation Testbed (CART) facilities. The associated increase in Argonne's FY 2001 operating resources for Environmental Processes (see KP-12 in Chapter VI) includes substantial DOE funding for redistribution to other national laboratories, universities, and subcontractors.

Argonne conducts research for the Atmospheric Chemistry and Environmental Meteorology components of the DOE-BER Atmospheric Sciences Program and provides the lead scientist for Atmospheric Chemistry. The Laboratory participates in collaborative field campaigns that gather information on the sources and fates of oxidants and particulate matter in the lower atmosphere and on associated meteorological processes. Associated DOE research addresses numerous scientific challenges related to the effects of energy-related trace chemicals on local and regional air quality and on climate. The work at Argonne emphasizes dry air-surface exchange, which affects the budgets of chemicals in the lower atmosphere; chemical transformations leading to oxidant and particle formation; and physical processes that transport materials vertically and horizontally in the lower one or two kilometers of the atmosphere.

The central goal of Argonne's work in synchrotron-based environmental science is an atomic- and molecular-level understanding of structure and processes in environmental systems. One set of studies focuses on mineral-fluid interactions and the mechanisms by which contaminant elements become bound to mineral surfaces. Other studies focus on developing synchrotron-based imaging techniques for environmental and biological samples and on understanding the speciation, binding, distribution, and mobility of heavy metals and radionuclides in soil-fluid-biota systems. These multidisciplinary efforts will build on the Laboratory's widely recognized research at the forefront of molecular radiation science and environmental science and will involve several new internal and external collaborations. See the discussion of the major initiative Synchrotron Environmental Science in Section IV.A.8.

Argonne is building and strengthening ongoing programs in site characterization and soil ecology. The Laboratory continues its R&D on environmental tools such as QuickSite®, a methodology that has become the basis for the American Society for Testing and Materials standard for expedited site characterization. In the area of soil ecology, new studies are under way on the importance of soils in sequestration of carbon dioxide and, in conjunction with the synchrotron-based environmental research, on the molecular-level processes that result in soil aggregation.

Environmental issues are salient worldwide and are especially significant in developing countries where economic activity is accelerating. Argonne has established a partnership with the Cairo University Center for Environmental Hazard Mitigation to investigate environmental problems in Egypt and to help train Egyptian scientists in state-of-the-art methods.

Initiative: Atmospheric Boundary Layer Experiments

Predicting the effects of climate change requires a much better understanding of extremely complex atmospheric phenomena. New technologies in remote sensing, instrumentation, computation, and data handling give atmospheric scientists an unprecedented opportunity to make significant advances quickly, if the technologies are integrated effectively at relevant spatial scales. More definitive insight into carbon cycling between the atmosphere and terrestrial ecosystems is a challenging objective that can best be accomplished by a national laboratory providing open access for the broad scientific community.

The Atmospheric Boundary Layer Experiments (ABLE) facility, located in the Walnut River Watershed near Wichita, Kansas, is providing shared state-of-the-art instruments and infrastructure for a broad community of scientists, which experience has shown to be the most efficient way to foster research across entire fields of science. Sharing of instrumentation eliminates unnecessary duplication. Neither industry nor academia alone could deploy instrumentation at the spatial scales and density required or support its long-term, continuous use, but both industry and academia will benefit greatly from its availability.

The ABLE facility is designed so that the basic measurements obtained are readily available to all interested scientists for their own research.

This approach facilitates the seamless integration of fundamental studies with mission-driven research. Active participation of national laboratory scientists ensures advancement across the entire relevant science and technology base.

Support by DOE-BER for ABLE is directed at understanding the flux of carbon between the atmosphere and terrestrial systems. Long-term estimates of the net ecosystem exchange of carbon, being constructed on the basis of micro-meteorological measurements, will be provided along with supporting data to the AmeriFlux data archive. In addition, ABLE is being considered a primary experimental site for DOE's participation in the national Water Cycle Initiative. Other ABLE activities include ongoing studies on the hydrological balance for the National Aeronautics and Space Administration's Land Surface Hydrology Program.

The ABLE facility is within the ARM Program's Southern Great Plains CART site, whose operation is managed by Argonne. ABLE experiments began in 1997. Integration of ABLE research with the activities of the larger CART site will continue. Funding is sought from a number of federal agencies, including DOE-BER (KP). Total resources required are summarized in Table III.6.

Table III.6 Atmospheric Boundary Layer Experiments ($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	0.5	1.0	1.5	2.1	2.5	2.5	2.5
Capital Equipment	0.2	0.2	0.2	0.5	0.5	0.5	0.5
Construction	-	-	-	-	-	-	-
Total	0.7	1.2	1.7	2.6	3.0	3.0	3.0
Direct Personnel	2.5	4.5	7.5	9.0	13.0	13.0	13.0

n. Science and Engineering Education and University Programs

Situation

Argonne has maintained very active and wide-ranging interactions with the academic community throughout its existence. The activities range from programs that support science education at the high school level to mutually beneficial research partnerships between university faculty and Argonne research staff in virtually all of the Laboratory's scientific and technical areas. These activities are supported by the Laboratory, through work for non-DOE sponsors, and by DOE.

Argonne's science and engineering education programs serve faculty and students at both the university and precollege levels. Core programs at the university level provide opportunities for research participation by outstanding undergraduates and faculty, as well as opportunities for thesis research by graduate students. Argonne has become more active in unique graduate programs involving several strategic areas of interest to DOE. The quality and value of these programs attract applicants from throughout the country.

As part of its education program, Argonne serves the Department of State as the host institution for U.S. participation in training programs of the International Atomic Energy Agency (IAEA). The Laboratory develops and conducts courses in peaceful applications of nuclear technology and also provides technical support to the State Department and the IAEA.

Vision

Argonne will enrich science education in the United States through activities that involve local communities, as well as students and faculty at all levels from throughout the nation. The Laboratory will work closely with DOE and other federal agencies to promote peaceful applications of nuclear technology through collaboration with the IAEA and other international organizations.

Objectives

Argonne's primary near-term objectives in support of science education and training are as follows:

- Continue to attract a large, diverse pool of highly qualified undergraduate students to research participation programs.
- Establish the Laboratory's educational user facility as a valuable and widely used resource providing hands-on laboratory experience for

science teachers in the region; enhance classroom activities through use of the Internet.

- Foster student interest in science education and science careers through a variety of outreach efforts.
- Fruitfully integrate graduate students, postdoctoral fellows, and faculty into Laboratory research programs through internships and training activities.
- Provide training programs and technical assistance to a variety of international organizations.

Issues and Strategies

For its university-level programs, Argonne plans special efforts to develop supplementary activities that will broaden the science horizons of undergraduates and provide training and research opportunities for graduate students. Programs for high school students and teachers will focus primarily on hands-on laboratory work using Argonne facilities and distance learning capabilities dedicated to educational activities. In addition, the Laboratory will continue to develop programs exploiting computer technology to enhance classroom science education. Important workshops and conferences, such as the annual Women in Science conference and a special program for underrepresented minorities, will continue. International programs will focus on unique Argonne research and training capabilities.

Maintaining a sound funding base is the most important issue currently facing Argonne's educational programs. Support for participants through the Office of Science has included limited infrastructure support. DOE offices with educational and training needs have been asked to consider the advantages of focusing those activities at Argonne. The Laboratory's research divisions plan to continue their strong support for the core educational programs of research participation and thesis research at the undergraduate, graduate, and faculty levels. Support for the operating costs of programs for precollege teachers in nearby school districts and in the Chicago Public Schools will be sought from the districts themselves, as well as from the state of Illinois, agencies of the federal government, and the private sector. Laboratory overhead will support the minimal infrastructure required to manage and administer these programs.

2. Energy Technologies

a. Energy and Industrial Technologies

Situation

Argonne develops innovative, efficient, cost-effective nonnuclear energy technologies and industrial technologies. Emphasis is on advanced transportation, "industries of the future" identified by DOE, superconductivity, and fossil fuels and carbon management. The program also coordinates the Laboratory's development of partnerships with private companies in these areas.

Advanced Transportation. Transportation accounts for about 25% of U.S. energy consumption and is 97% dependent on petroleum. With the transportation sector alone now using twice as much petroleum as the United States produces, imported oil has become an increasing concern for energy security and the balance of trade. Emissions from motor vehicles are primarily responsible for urban air pollution, and one hundred million Americans live in 38 urban areas across the country that exceed federal standards for ozone. Moreover, because it accounts for a third of U.S. emissions of carbon dioxide, transportation is central to global warming concerns. Cars and light trucks are the major consumers of petroleum products, so switching to nonpetroleum fuels or increasing energy efficiency could alleviate energy security and environmental concerns. R&D sponsored by DOE's Office of Transportation Technologies aims to improve the energy efficiency of both cars (through the Partnership for a New Generation of Vehicles program) and trucks (through the Heavy Vehicle Technologies program).

"Industries of the Future." Process industries convert raw materials into ingredients useful for fabrication and assembly in the automotive, electronics, aerospace, construction, and similar industries. The process industries account for approximately a third of U.S. energy consumption, at an energy cost of about $100 billion each year.

Six of the major process industries — chemicals, forest products, glass, ceramics, metals, and petroleum refining — account for 78% of all industrial energy use, generate 95% of manufacturing waste, cause 95% of the total air pollution attributable to manufacturing, and account for more than 30% of U.S. carbon dioxide emissions. Because they use so much energy and produce so much waste, the federal government has set goals for U.S. process industries for the year 2010 in terms of energy reduction, oil displacement, cost savings, and pollution reduction.

Superconductivity. The electric power industry today faces a wide range of major challenges, including deregulation, aging infrastructure, global warming policies, and dependence on imported oil. Power wheeling across long distances puts a premium on technologies for the transmission and distribution of electric energy that are efficient and robust, and greater interconnectedness necessitates better technologies to protect against overloads and fault currents. Renewable energy sources are increasingly attractive, but solar or wind energy is intermittent and requires energy storage. High-temperature superconductivity technologies are being pursued by DOE and increasing numbers of electric power utilities and their suppliers as a promising response to many of these challenges.

Fossil Fuels and Carbon Management. A prudent carbon management strategy for the utility, industrial, and transportation sectors could significantly decrease emissions of carbon dioxide and other greenhouse gases released in the burning of fossil fuels. These sectors are already adopting more energy-efficient technologies. Strategies for the economic use of less carbon-intensive fuels in existing plants and fleets may be an important bridge to more advanced technologies. However, a full assessment of policy options will require better understanding of carbon transformations from "cradle to grave," throughout current and proposed energy cycles. Argonne initiatives support DOE strategies to improve the efficiency of fossil energy technologies and to assist the utility, industrial, and transportation sectors in reducing greenhouse gas emission rates in other ways as well.

Partnering. Responding to the administration goal of improving the productivity of U.S. industry through appropriate use of national technical resources, Argonne is developing a broad range of partnerships with industrial firms on the basis of the Laboratory's leadership in many areas of science and technology. Argonne's midwestern location in the nation's industrial heartland provides exceptional regional opportunities. R&D partnerships between the national laboratories and U.S. industry have become even more critical to the economic health of the nation over the past two decades, as increasingly competitive markets have forced companies to focus on the near term rather than investing in long-term R&D. Partnerships with industry play an important role in shaping many Argonne R&D programs.

Vision

Argonne will develop new technologies that increase the productivity of U.S. industry and decrease its environmental impacts, particularly through increases in energy efficiency and reductions in intensity of petroleum consumption. As an integral part of pursuing its mission in science and technology, the Laboratory will continue to develop effective relationships with industry to maximize the commercial applications and benefits to the nation from its R&D.

Goals and Objectives

To implement this vision, Argonne's goals include the following:

- Exploit and expand Argonne facilities, capabilities, and core competencies, which integrate science and technology and interest both the scientific and industrial communities.
- Establish strategic partnerships with key industrial firms, large and small, in areas where applying the Laboratory's technical strengths is most likely to lead to valuable commercial successes.
- Implement effective regional outreach, capitalizing on the Laboratory's midwestern location.

Many U.S. industries are working with the federal government to ensure that federally sponsored R&D provides maximum benefits to the nation. Consistent with the DOE *Strategic Plan*, Argonne has established the important research objectives summarized below, which are being pursued in close partnership with industry.

Advanced Transportation: Transportation Technology R&D Center

• Work with the Partnership for a New Generation of Vehicles (which includes the DOE Office of Advanced Automotive Technologies, Ford, General Motors, and DaimlerChrysler)

- To develop by 2004 an 80-miles-per-gallon family sedan that is fuel flexible, meets all applicable emission and safety standards, and costs no more to own and operate than conventional vehicles of comparable size and

- To develop processes for economically recycling virtually all material from obsolete automobiles.

• Work with DOE and truck engine manufacturers (such as Caterpillar, Cummins, Detroit Diesel, and Navistar) to advance the state of diesel engine technology and allow high-efficiency, compression-ignition, direct-injection engines to be used in vehicles of all sizes.

- For heavy-duty (tractor trailer) trucks, develop flexible-fuel, low-emission engines achieving 10 miles per gallon rather than today's 6 to 8.

- For medium-duty (commercial delivery) trucks, adapt high-efficiency engine technology from heavy-duty trucks.

- For light-duty (pickup) trucks, develop fuel-flexible, efficient, low-emission diesel engines with gas mileage 35% better than in 1997.

• Develop new technology enabling the 6,000-horsepower, 16-cylinder, 4-stroke, diesel-locomotive engine of the General Motors Electro-Motive Division to meet federal emissions requirements expected in 2004, while it still achieves high efficiency.

• Develop advanced railroad technologies identified in consultation with the Association of American Railroads and other industry stakeholders.

• Develop and help to implement new technology and techniques allowing improved traffic control and safety in "intelligent transportation systems," under sponsorship of the U.S. Department of Transportation and the transportation authorities of Illinois, Indiana, and Wisconsin, focusing on the Gary-Chicago-Milwaukee corridor.

• Conduct risk analyses, analyze cask designs, and develop improved tracking systems for the transport of hazardous materials.

Industries of the Future

• Expand Argonne research benefiting the chemical industry, particularly research in the areas of recovery and reuse of polymers, development of chemicals from alternative feedstocks, catalysis, and plasma-chemical engineering.

• Further develop advanced technologies that improve petroleum refining by developing advanced computational modeling for fluid catalytic cracking to improve overall yields.

• Conduct expanded research for the forest products industry, building on current work in the areas of plasma-chemical treatment of volatile organic compounds, recovery of nonprocess elements, application of sensors and instrumentation, and neural-net process control.

• Maintain the momentum of current research on metals recycling; expand work on instrumentation, materials, and fabrication technologies for the steel, aluminum, glass, and metal casting industries.

• Target key technical hurdles where unique Argonne capabilities and facilities can be used to advantage; for example, use the Advanced Photon Source and the Intense Pulsed Neutron Source for critical materials studies that will enable the development of inert metal anodes for aluminum smelting.

• Advance the development of nearly frictionless, nontoxic carbon coatings for moving parts (such as oilless bearings, spacecraft mechanisms, rolling and sliding gear systems, and bearings for ultrahigh-vacuum instruments like X-ray tubes), while contributing more broadly to tribology.

Superconductivity

• Continue Argonne's contributions to the development of the second generation of high-temperature superconductors, building on successes with powder-in-tube technology.

• Develop a practical flywheel for energy storage based on high-temperature superconducting bearings.

• Design a totally new high-temperature-superconducting fault-current limiter that represents a major advance in the state of the art.

• Develop an electric motor based on a new design using high-temperature superconductors.

• Develop an improved superconducting electricity transmission cable.

• Work with the manufacturers of high-temperature superconducting wire (such as American Superconductor Corporation and Intermagnetics General Corporation) to help advance manufacturing processes.

• Collaborate with system manufacturers (such as Boeing, Southwire, and S&C Electric Company) to develop and demonstrate energy-efficient electric power technology products.

Fossil Fuels and Carbon Management

• Expand and help coordinate the development of technologies that are cost-effective and highly efficient, emit smaller amounts of greenhouse gases, and reduce environmental impacts in the utility, industrial, and transportation sectors; establish emissions inventories for promising technologies and link industrial partners to pursue technology development.

• Advance petroleum refining technology by developing (1) catalysts for upgrading heavy crudes and residuum and (2) catalytic hydroprocessing to produce ultraclean low-sulfur transportation fuels through heteroatom removal.

• Investigate opportunities for sequestering carbon dioxide released from advanced fossil fuel energy systems.

• Improve understanding of terrestrial and oceanic responses to natural and anthropogenic changes in atmospheric concentrations of greenhouse gases.

• Develop a center for research on biogeochemical cycling of elements.

• Investigate novel natural gas resources, especially the methane hydrates distributed in ocean sediments throughout the world, giving special consideration to ocean margin stability.

• Expand R&D on noncarbonaceous hydrogen production.

• Continue R&D on proton-conducting ceramic membranes as an economic way to produce hydrogen gas.

• Extend Laboratory breakthroughs in ceramic membrane technologies to advance the development of economic processes for separating oxygen from air and hydrogen from mixed gases (which are critical technologies in the use of remote natural gas and the efficient refinery production of ultraclean transportation fuels); establish a center for research on ceramic membranes to develop enabling technologies in a new approach to energy production from fossil fuels (DOE's Vision 21).

Issues and Strategies

Transportation. Through its Transportation Technology R&D Center, Argonne conducts comprehensive research on advanced diesel engines (combustion modeling, emissions, sensors, coatings, lubricants, and assessments), energy storage devices (batteries and ultracapacitors), low-friction materials for vehicles, hybrid vehicles, fuel cells, transportation-related supercomputing, vehicle recycling, railroad systems, sensors for intelligent transportation systems, data processing technology, and risk and hazard analysis. The Laboratory's initiative in Advanced Transportation Technologies is discussed below.

Industry. Through the auspices of the DOE Office of Industrial Technologies, Argonne is working closely with the following industry associations to apply the Laboratory's skills, facilities, and core capabilities:

- Chemicals: Council for Chemical Research
- Refining: American Petroleum Institute
- Forest products: American Forest and Paper Association
- Steel: American Iron and Steel Institute
- Aluminum: Aluminum Association
- Metal casting: Cast Metal Coalition
- Glass: Glass Manufacturers Industry Council

In other work, an Argonne initiative aims to develop less costly biotechnological methods of producing valuable chemicals from agricultural materials. See the discussion of Biobased Chemicals in Section III.D.1.l.

Superconductivity. There is increasing conviction among electric utilities and their suppliers that new technology based on high-temperature superconductivity will provide substantial benefits. This industry support is reflected in recent increases in DOE funding of R&D in the area. Several respected international studies have predicted that global annual sales for all technologies based on high-temperature superconductivity will reach billions of dollars by the year 2020. International competition for these sales will be strong, particularly from Japan and Western Europe.

Argonne is uniquely positioned to develop new technologies based on high-temperature superconductivity. The Laboratory's program of basic science in the field is the strongest in the world. Close cooperation with the Laboratory's applied superconductivity program, which has already produced many notable achievements, is the basis for future efforts. Argonne plans to be a major contributor to the development of the second-generation conductor, building on industrial successes already achieved with first-generation powder-in-tube technology. The Laboratory also is developing a flywheel incorporating superconducting bearings that could be among the first commercially successful electric power equipment based on high-temperature superconductivity. Argonne will expand the range of utility applications on which it works, taking advantage particularly of new ideas for fault-current limiters, transmission cables, and motors based on superconductivity. Work in nonutility applications will expand as well, on the basis of innovative ideas in areas such as magnetic separation.

Fossil Fuels and Carbon Management. In Congress, there appears to be growing bipartisan support for DOE research related to carbon management. Budgets proposed for FY 2001 include substantial increases for work in this area within the Office of Fossil Energy and the Office of Science, despite an overall budget decrease for Fossil Energy. A consortium of major petroleum companies is working with the Office of Fossil Energy toward developing major field demonstrations of technologies for the economic sequestration of carbon dioxide.

Partnering. Congressional appropriations have continued to reduce funding explicitly available for participation by DOE in industrial partnerships. Argonne's industrial partnerships will be severely constrained, unless this trend is reversed.

DOE has established policies that restrict Laboratory participation as a partner with industry in responding to federal RFPs (requests for proposals). Implementation of this policy shift has severely reduced the Laboratory's ability to develop partnerships with industry, many of which are formed in response to RFPs from DOE or other federal agencies. Argonne urges reconsideration of this policy change, whose effect runs counter to the goals, objectives, and strategies of the DOE *Strategic Plan*.

To maximize the likelihood of establishing effective industrial partnerships in the most promising area of technology, Argonne is seeking opportunities to include other national laboratories and universities in productive strategic collaborations based on the Laboratory's scientific and technical capabilities and its core competencies. The Laboratory has already established a vigorous regional outreach program whose broad goal is to help manufacturers in the Midwest. The Laboratory measures the success of its industrial partnerships by considering the significance and impact of the work accomplished and of the ultimate successful commercialization of new technologies.

Initiative: Advanced Transportation Technologies

Argonne plans to expand its current R&D and analysis of advanced technologies for DOE and other sponsors through its Transportation Technology Research and Development Center. Collaborative R&D is key to addressing the nation's transportation problems, and the center benefits from the Laboratory's location in the midwestern heart of the nation's automotive, truck, and railroad manufacturing industries. The general objective is to develop and implement cost-effective technologies to improve the fuel efficiency of advanced transportation systems and to reduce their environmental emissions. Specific strategies for eight technology areas are as follows:

- *Advanced Diesels*. Diesel engines offer potential for significant improvements in the fuel economy of automobiles, and they can be enhanced to provide greater efficiencies in trucks and locomotives. By using permeable membranes to create oxygen-rich and nitrogen-rich streams from ambient air, Argonne plans to extend its success in emissions control to develop advanced air composition techniques and fuel injector systems that simultaneously reduce emissions of particulates and nitrogen oxides from diesel engines of all sizes. Industrial partners include Caterpillar, Compact Membrane Systems, the Electro-Motive Division of General Motors, and Robert Bosch.

- *Energy Storage Devices*. Bolstered by stringent environmental regulations and legislative mandates in California and elsewhere, the market for electric vehicles is expanding. In response, General Motors, Ford, and Chrysler (now DaimlerChrysler) formed the U.S. Advanced Battery Consortium, a partnership with DOE and the Electric Power Research Institute, to develop advanced batteries for electric vehicles. The Laboratory — along with Lawrence Berkeley, Brookhaven, and Sandia National Laboratories — is working to develop commercially viable high-power lithium-ion batteries as energy storage devices. Argonne's R&D ranges from materials research on improved anodes and cathodes to the development of novel low-cost packaging concepts for lithium-ion batteries.

- *Hybrid Vehicles*. Hybrid vehicles promise to overcome the limitations of electric vehicles — especially range and recharging rate. Hybrid vehicles employ either a small internal combustion engine or a gas turbine, along with a battery or ultracapacitor, allowing them to perform like a conventional vehicle but be far more energy efficient and environmentally benign. Argonne's Advanced Powertrain Test Facility is gathering performance and emissions data for hybrid vehicle components and is validating models that simulate the performance of hybrids. Direct-measurement capabilities are being added.

- *Fuel Cells*. Fuel cells convert chemical energy directly into electrical energy, cleanly and efficiently. Potentially, fuel-cell-powered vehicles could nearly double the energy efficiency of conventional vehicles and reduce emissions by 99%. Through its R&D on fuel cell components and fuel-processing technology, Argonne has developed a partial-oxidation reformer that converts gasoline to hydrogen-rich gas for use in polymer-electrolyte-membrane fuel cells. The reformer is being scaled up and modified to serve as a prototype amenable to low-cost, high-volume manufacturing.

- *High-Performance Computing*. As part of the Supercomputer Automotive Applications Partnership — an R&D consortium under the aegis of the U.S. Council for Automotive Research — Argonne and other DOE laboratories are collaborating with domestic automakers. The goal is to create computer software for systems that cut the time required to design and test new concepts for aerodynamic shapes and improved safety features. The focus is the fluid dynamics of underhood cooling, a critical design consideration for hybrid vehicles.

- *Recycling*. Obsolete motor vehicles contain plastics, chlorofluorocarbons, rubber, glass, and heavy metals that are not yet recyclable and must be deposited in landfills. Under the Vehicle Recycling Partnership with domestic automakers, Argonne will develop technologies for processing waste streams resulting from the recycling of advanced vehicles having new structural materials and propulsion systems.

- *Railroad and Electromagnetic Technologies*. To maintain and improve the ailing U.S. railroad system and to meet future demands for increased fuel efficiency, reduced emissions, higher speeds, and greater axle loads, Argonne and other DOE-Science laboratories are partnering with the Association of American Railroads. The Laboratory is also serving as DOE's technical lead in a cooperative government-industry magnetic-levitation (maglev) research program mandated by authorizing legislation for the U.S. Department of Transportation.

- *Intelligent Transportation Systems*. To make driving on U.S. streets and highways safer and more efficient, Argonne has joined a national effort to improve automotive transportation through intelligent transportation systems that rely on advanced electronics and communications, computing, sensors and instrumentation, and information management. This work exploits the Laboratory's experience in complex computer simulations.

Funding for this research is sought from the Laboratory Technology Research Program (KU) of DOE-Science, from two programs within DOE-Energy Efficiency (Transportation [EE] and Industrial [ED]), and from the Department of Transportation. See Table III.7.

Table III.7 Advanced Transportation Technologies ($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	31.4	33.0	34.5	34.5	34.5	34.5	34.5
Capital Equipment	1.0	1.5	1.5	1.5	1.5	1.5	1.5
Construction	-	-	-	-	-	-	-
Total	32.4	34.5	36.0	36.0	36.0	36.0	36.0
Direct Personnel	105.0	105.0	105.0	105.0	105.0	105.0	105.0

b. Advanced Nuclear Technology

Situation

Throughout its history, spanning more than 50 years, Argonne has been a leader in the development of nuclear reactors. As a result, the Laboratory has broad, unique expertise in the full range of disciplines associated with nuclear reactor technology, as well as a full complement of experimental facilities. However, the U.S. nuclear technology infrastructure, which once led the world, has been eroded seriously and could be lost entirely if present trends continue. Currently, DOE support for nuclear reactor technology is focused primarily on (1) the Nuclear Energy Research Initiative (NERI), which aims at innovative reactor concepts, nuclear science, and nuclear technology; (2) the Nuclear Energy Plant Optimization program, which addresses critical technology issues associated with existing nuclear power plants; and (3) efforts to improve the safety of nuclear reactors worldwide, with primary attention to Soviet-designed reactors and the countries operating these reactors. DOE is increasingly emphasizing international collaborations through proposals for a new international component to the NERI and through proposed programs for collaborative R&D on nuclear fuel cycle options that maximize technological barriers to proliferation.

In the future, nuclear energy must contribute increasingly to the world's energy supply if major environmental goals are to be met. To meet such goals, DOE and Argonne must play an expanding role in advanced nuclear technology to provide technical leadership and stewardship for the nation's expertise and facilities.

Vision

Argonne will continue its historic role of technical leadership in nuclear technology. The Laboratory will develop innovative technologies, test and demonstrate them at Argonne-West facilities and elsewhere, and ultimately apply them to the highest-priority issues of nuclear energy. Argonne will expand its role in international nuclear safety through the International Nuclear Safety Center (INSC) and other cooperative projects. In cooperation with the Idaho National Engineering and Environmental Laboratory (INEEL), Argonne will serve as lead laboratory for reactor technology for DOE's Office of Nuclear Energy, Science and Technology. The Laboratory will also have major roles in international collaborations in nuclear technology.

Goals

The goals of Argonne's nuclear technology program are to pursue aggressively solutions to the important technical issues associated with the use of nuclear energy, both domestically and internationally; to support the related nuclear science and technology programs of DOE; and to maintain a set of technical capabilities in nuclear science and technology — including both expertise and infrastructure — sufficiently broad and deep to address a full range of national needs.

Strategies

Argonne proposes a nuclear energy R&D program with the following objectives:

- Maintain a complete core competency in nuclear technologies, so that a nuclear option remains available to the United States for the long term.
- Conduct research into innovative concepts and technologies for safer, more efficient, more environmentally acceptable nuclear reactors.
- Support continued safe and efficient operation of current nuclear power plants, in order to protect near-term energy security and to serve as a bridge to longer-term objectives.
- Support bilateral and multilateral international R&D collaborations and safety improvement projects, so that the worldwide nuclear technology enterprise achieves continuous improvement in safety and reduced risk of proliferation.
- Conduct educational and training activities for U.S. and international participants, to improve knowledge of nuclear technology worldwide and to ensure a high level of capability in the staffs of safety oversight and regulatory agencies.

Key strategies for Argonne's nuclear technology programs include the following:

- Continue to participate in the NERI; apply Argonne's nuclear expertise and unique facilities to research on advanced reactor technologies and innovative reactor concepts; participate in projects on accelerator-driven reactor systems.
- Continue to operate the INSC and participate in the Soviet-Designed Reactor Safety Program; develop further international collaborations and projects, including collaborative bilateral and multilateral R&D, education and training, and technical assistance.
- Apply Argonne's expertise to address critical issues affecting continued safe and efficient operation of existing nuclear power plants.
- In partnership with INEEL, serve as lead laboratory for reactor technology for DOE's Office of Nuclear Energy, Science and Technology.

These goals and strategies are discussed further in a major Laboratory initiative presented in Section IV.B.1. Programmatic initiatives addressing several specific technical needs follow immediately below.

Initiative: Advanced Fuels Development

Argonne proposes an initiative in the development of advanced fuels for power reactors and for research and test reactors. For many years, the Laboratory has been a leader in nuclear fuel

R&D. Work focused most recently on the ternary-alloy metal fuel for the Integral Fast Reactor program and on high-density, low-enrichment fuels for the Reduced Enrichment for Research and Test Reactors (RERTR) program. Over the years, Argonne has conducted experiments and examinations on many types of oxide and metal fuels, and the Laboratory maintains a full capability for handling uranium- and plutonium-bearing fuels. In this initiative, Argonne proposes to collaborate with INEEL in the development of high-efficiency light-water reactor (LWR) fuels, the development and testing of mixed-oxide fuels, and the development of advanced research reactor fuels.

New concepts and designs are needed for high-efficiency LWR fuels capable of high-burnup with improved safety margins. In order to develop such fuels, the proposed joint Argonne-INEEL program would use INEEL's Advanced Test Reactor for extended-burnup irradiation testing of modern and advanced LWR fuels and then use the Transient Reactor Test Facility at Argonne-West for subsequent experiments to address transients and accident simulations. The Hot Fuel Examination Facility at Argonne-West, the Alpha-Gamma Hot Cell Facility at Argonne-East, and hot cells at INEEL's Test Area North would be used for preparation of test fuel rods, for some types of testing, and for posttest examination and characterization.

The objectives of the proposed program are as follows:

- Improve the reliability and safety margins of LWR fuel, in order to prevent fuel defects and forced shutdowns.
- Significantly increase the energy generated by each fuel loading, in order to achieve longer refueling cycles, higher capacity factors, and less costly electric power.
- Significantly reduce the volume of spent nuclear fuel eventually requiring disposal, by extracting more energy from the fuel prior to discharge.
- Develop fuel that is much more resistant to proliferation.

The program will feature a three-pronged approach:

- Determine the useful lives of the best fuels currently used in commercial nuclear power plants.
- Improve fundamental understanding of the life-limiting degradation mechanisms in nuclear fuel at high burnup.
- Design and test advanced and innovative forms of LWR fuel.

Initiatives such as the NERI and discussion of a potential Generation-IV reactor system have given technologists the opportunity to consider innovative reactor technologies and propose research to address concerns about proliferation of weapons-usable materials, the economics of power generation, disposal of waste by-products, and perceptions of safety. Although a variety of different system configurations are being discussed (such as systems whose coolants are based on water, gas, or lead), a common feature specified for most is a new fuel design. New fuel designs will be key to enhancing proliferation resistance and improving costs, particularly if long-exposure (high-burnup) fuel is used.

Development of metal-alloy fuels under the U.S. fast reactor programs (most recently, through the Integral Fast Reactor program) demonstrated that metal fuels offer attractive safety features and simplified fabrication and quality assurance requirements. However, that experimental work also indicated that reactor operation with certain metal fuel forms is limited to relatively moderate temperatures. Nevertheless, metal-matrix dispersion fuels are demonstrably capable of high-burnup exposure, and they potentially offer the safety advantages of metal-alloy fuels coupled with a high-burnup fuel design.

Argonne is therefore pursuing the development of metal-matrix fuels through several efforts. The current Accelerator Transmutation of Waste (ATW) program is funding a six-year, science-based evaluation of relevant technologies. That program includes the development of a nonfertile fuel form for an ATW system, one candidate for which is a metal-matrix fuel form. In addition, Argonne's Laboratory Directed R&D (LDRD) program is supporting a project that will investigate metal-matrix fuel concepts employing refractory metals for high-temperature applications. In addition to these funded projects, Argonne has proposed a NERI project that would build on the LDRD project to develop concepts for metal-matrix fuels for Generation-IV reactor systems.

Resources required for this initiative are presented in Table III.8. Funding is sought from DOE-Nuclear Energy, Science and Technology (AF).

Table III.8 Advanced Fuels Development
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	-	0.5	2.8	3.7	4.9	4.9	4.9
Capital Equipment	-	2.6	3.0	2.4	1.1	0.6	0.6
Construction	-	-	-	-	-	-	-
Total	-	3.1	5.8	6.1	6.0	5.5	5.5
Direct Personnel	-	8.0	12.5	14.0	16.0	16.0	16.0

Initiative: Transient Testing at TREAT

Argonne proposes to reactivate the Transient Reactor Test Facility (TREAT) to carry out a variety of tests needing a reactor capable of producing controlled transients. Transient testing of the kind required for certain missions can be performed only in special test reactors, of which there are but a few in the world. TREAT, located at Argonne-West and now in a standby status, is one such facility. Two potential testing missions are currently under discussion. The first involves helping industry and regulators assess safety margins for new fuel designs for commercial LWRs. The second is assessment of safety issues for advanced fuel concepts, particularly concepts that might be considered for Generation-IV reactor systems.

Development of fuels for commercial power reactors capable of extended burnup and other advanced performance will require transient testing, for which the TREAT facility is uniquely well suited. A key to achieving greater efficiency in a commercial reactor is use of fuel capable of higher burnup levels. Such fuels must perform reliably during normal operation and during hypothetical accidents — including reactivity-initiated accidents (RIAs) — allowed for in the original design of the commercial reactor and its fuel. Recent simulations of RIAs in transient test reactors have suggested that fuel irradiated to current burnup limits might be more susceptible to failure than was originally believed. Additional experiments are required if present burnup limits are to be extended, either by permitting fuel of current designs to be used to much higher burnup levels or by licensing the use of ultrahigh-burnup fuel types yet to be developed. Moreover, innovative reactor concepts designed for new markets and improved proliferation resistance may require new fuels. For licensing, such new fuels will, in turn, require a new safety database based on in-pile experiments.

The recent testing of high-burnup fuels was performed in foreign test reactors that were unable to provide prototypical conditions. (For example, the pulse widths were far too narrow, and the coolant heat transfer conditions did not simulate those in LWRs well.) This limitation creates uncertainties in interpreting test results. In fact, no facility in the world is currently capable of performing tests of high-burnup fuel in a high-pressure flowing-water environment typical of that in a pressurized-water reactor core during an RIA. If a high-pressure water loop is installed in TREAT and modest modifications are made to enhance TREAT's neutronics capabilities, Argonne-West will host the best facility in the world for RIA transient testing and potentially for addressing other fuel performance issues for LWRs and other reactor types.

Under this initiative, Argonne would design, fabricate, and install (1) the necessary water loop and associated equipment in TREAT, along with supporting facilities, and (2) the neutronic enhancements required for the reactor. Concurrently, activities needed to restart the TREAT facility will be pursued, and an experimental program will be developed to provide needed information on the behavior of domestic and foreign fuels.

Government agencies and industry, both foreign and domestic, are envisioned as potential sponsors for this TREAT program. With support from DOE, a TREAT test program can be offered to external sponsors at a typical cost of about $700,000 for a fuel safety test. The desired DOE funding level for a TREAT testing program ranges from $5 million to $7 million per year, which will support the operations crew at Argonne-West and the experimentation group at Argonne-East. The first test at the enhanced TREAT would be performed early in the fourth year of the program.

Although discussions of Generation-IV reactor systems are still preliminary and no such system exists today, even as a conceptual design, a consensus about several attributes or requirements for such systems seems to be emerging. In all cases, technologists are considering innovative reactor technologies that can address concerns about proliferation of weapons-usable materials, economics of power generation, disposal of waste by-products, and perceptions of safety. These reactor concepts will require new fuel designs, possibly even new fuel forms. Because enhanced safety will be an absolute requirement for Generation-IV reactor systems, reduction in the frequency and severity of postulated accidents will be a primary R&D objective.

New fuel systems require evaluation of behavior under the types of off-normal events envisioned for the newly conceptualized reactor systems. However, early evaluations from safety experiments designed according to previous experience with fuel performance and safety will provide important feedback to developers of reactors and fuels. Such early feedback allows developers to use a science-based approach to identify and pursue the technological options having the greatest potential for success.

Argonne anticipates that transient tests of new fuel forms and designs will be required early in the emerging efforts to develop Generation-IV reactor technology. Since DOE views Generation-IV development as an international effort, the testing program likely would also be international. The Laboratory is contacting potential international collaborators and is seeking support for preliminary studies to assess the safety of advanced concepts.

Required resources are summarized in Table III.9. Funding is sought from DOE-Nuclear Energy, Science and Technology (AF).

Table III.9 Transient Testing at TREAT
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	-	6.0	7.3	5.2	6.4	6.4	6.4
Capital Equipment	-	1.0	1.0	1.0	0.1	0.1	0.1
Construction	-	-	-	-	-	-	-
Total	-	7.0	8.3	6.2	6.5	6.5	6.5
Direct Personnel	-	30.0	36.0	26.0	32.0	32.0	32.0

Initiative: Materials Technology for Nuclear Power

Effective mitigation of carbon dioxide emissions, now and in the future, requires continued safe, efficient operation of nuclear power plants and development of new reactor designs with improved efficiency and security for use worldwide. DOE's strategic objectives include support of innovative research and science for nuclear energy and addressing of critical technology issues associated with existing nuclear power plants. As part of this effort, Argonne will address the structural integrity of stainless steel components inside the reactor that are critical to safe, efficient operation. This work will seek to understand irradiation embrittlement of the stainless steels through tensile testing and development of complete constitutive laws for deformation, as well as through analysis of the mechanisms of irradiation embrittlement. Ultrasmall test specimens will allow efficient use of the limited available supply of radioactive surveillance samples. Testing will be performed in hot cells, and measurements will be made in Argonne's Advanced Photon Source. In addition, advanced, more efficient reactors operating at higher temperatures will require new heavy-liquid-metal (HLM) coolant technology. Under this initiative, Argonne will explore the effects of HLM exposure of advanced high-temperature alloys. These same materials and HLM technology will be applied to ferritic stainless steels in the development of facilities for the accelerator transmutation of waste.

The degradation of stainless steel components in reactors is manifested by increased fracturing and reduced ductility. Currently, Argonne is developing deformation behavior models that can be used, in conjunction with research on environmentally influenced fracture mechanisms and the effects of welding of irradiated materials, to develop tools to predict component life, assess nondestructive examinations, and guide the timing of corrective actions. In addition, models of irradiation-assisted stress corrosion cracking will be developed to help understand the effects on susceptibility of alloy composition, fluence, stress level, and grain boundary structure.

Cost-effective maintenance of energy generation systems requires the ability to assess the condition of component materials. For example, defects in steam generator tubing can be characterized by using current nondestructive evaluation techniques. To address this issue, Argonne proposes to develop an automated artificial neural network to interpret more accurately eddy current and ultrasonic signals from degraded tubes. This technique can give a more accurate characterization of flaws and can aid the prediction of remaining tube life. Moreover, the technique promises to have many valuable applications in other industries and technologies.

Resources required for this initiative are described in Table III.10. Funding will be sought from DOE-Nuclear Energy, Science and Technology (AF).

Table III.10 Materials Technology for Nuclear Power ($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	-	1.1	2.2	2.6	2.6	2.6	2.6
Capital Equipment	-	-	0.4	-	0.2	-	-
Construction	-	-	-	-	0.5	-	-
Total	-	1.1	2.6	2.6	3.3	2.6	2.6
Direct Personnel	-	5.0	10.0	12.0	12.0	12.0	12.0

Initiative: Post-Operation Evaluation of EBR-II Materials and Components

The Experimental Breeder Reactor-II (EBR-II) was shut down in 1994 after more than three decades of successful operation with little unscheduled downtime. A fast reactor cooled with liquid metal (sodium), EBR-II was a complete electrical power generating system tied into the local commercial power grid. It was also a certified cogeneration system that provided steam for space heating. The shutdown of this successful, long-running reactor offers a unique opportunity to examine a reactor and its plant components and materials, which have had extended exposure to thermal and radiation environments. A complete knowledge of materials and components conditions for both EBR-II and similar reactors around the world will facilitate future decommissioning activities and will benefit the life extension of other reactor types.

Understanding the effects of radiation on core components (mechanical property degradation, swelling, susceptibility to environmentally assisted cracking, etc.) is critical to extending the life of LWR plants. EBR-II materials and components have experienced long exposures to irradiation and thermal environments; some were removed from the reactor in anticipation of these analyses, and others are accessible for removal. These EBR-II components were irradiated at dose rates and temperatures similar to those experienced by some pressurized-water reactor components, at exposures equivalent to or exceeding current and extended-life conditions. In many cases, such materials and components have never before been available for examination.

Argonne is investigating ways of removing EBR-II materials and components and examining them, along with materials and components that have already been removed. Phenomena of interest are being related to particular components and their accessibility. Final decisions about topics for study will depend on support from sponsors. Already, several contracts are in place to examine specific stainless steel and nickel-based materials relevant for life extension of LWRs. Two contracts with non-DOE sponsors are under way to investigate the swelling, microstructure, and mechanical properties of irradiated 304 and 316 stainless steel hexcan material.

The central purpose of this initiative is to expand significantly the examination of EBR-II materials and components, so that these extremely valuable data are not lost. The most important application will be in life extension and license renewal for LWRs. Funding (Table III.11) will be requested from DOE-Nuclear Energy, Science and

Technology (AF). Additional funding to support engineering assistance for component retrieval will be requested from DOE-Environmental Management.

Table III.11 Post-Operation Evaluation of EBR-II Materials and Components
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	-	1.5	1.5	1.5	1.0	0.5	0.5
Capital Equipment	-	1.0	0.8	0.2	-	-	-
Construction	-	-	-	-	-	-	-
Total	-	2.5	2.3	1.7	1.0	0.5	0.5
Direct Personnel	-	3.0	3.0	2.0	2.0	1.5	1.5

Initiative: Severe-Accident Management Technology

Argonne's initiative in severe-accident management builds on the Laboratory's extensive expertise in reactor safety research, derived from decades of forefront contributions to plant safety analyses, risk studies, and investigations of regulatory issues. This research initiative addresses the question of what could be done at a nuclear power plant if a core melt accident were to occur. Specifically, ways are sought to (1) minimize the threat that core melt progression poses to containment integrity, (2) terminate and stabilize an accident as early as possible, and (3) minimize the release of harmful radioactive materials to the environment. Central to this initiative are Argonne's comprehensive, unique facilities for conducting research on severe core damage, as well as its extensive resources in the areas of computer codes, materials properties, and relevant databases.

Argonne is already working collaboratively with a number of prominent foreign and domestic organizations to address important topics in accident management. For example, under the auspices of the International Nuclear Safety Center, the Laboratory is working with Russian organizations to develop the technology base for their severe-accident management program. This work includes adaptation of the U.S. MELCOR code to the Russian RBMK reactor system. Argonne is also performing research — the Melt Attack and Coolability Experiment or MACE program — for an international consortium headed by the Electric Power Research Institute, to investigate ways to terminate molten core penetration into the massive concrete pad ("basemat") on which the reactor is built and thereby prevent radiation release. In addition, the Laboratory is working with the Canadians to address issues relating to steam explosion energetics for their CANDU reactors.

Argonne's facilities for conducting experiments on severe-accident management, collectively known as "the MACE facility," are increasingly recognized worldwide as a unique R&D asset. This complex, located at Argonne-East in Building 315 (housing the MACE containment cell, experiment preparation facilities, and archival storage facilities) and Building 206 (housing technology development and small experiment facilities), has provided essential experimental data on the behavior of real materials that are important for severe-accident management. The MACE facility has been nominated by the U.S. Nuclear Regulatory Commission to the Organization for Economic Cooperation and Development (OECD) for designation as an international reactor safety R&D facility. Argonne is developing a proposal for R&D programs to be carried out at the MACE facility under OECD auspices.

Argonne's Severe-Accident Management Technology initiative supports the Laboratory's historic mission in advanced nuclear technology, particularly in the development and evaluation of technologies to reduce risks associated with nuclear power plant accidents. Resources required are described in Table III.12. Funding is sought from the DOE Office of Nuclear Energy, Science and Technology (AF); from the U.S. Nuclear Regulatory Commission; from the International Nuclear Safety Program; and from other foreign and domestic organizations.

Table III.12 Severe-Accident Management Technology ($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	-	-	-	-	-	-	-
Total	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Direct Personnel	3.5	3.5	3.5	3.5	3.5	3.5	3.5

Initiative: Advanced Modeling and Simulation for Engineering Applications

Advances in computing, visualization, and communication technologies offer important new opportunities for simulating, diagnosing, and analyzing engineering systems and components at levels of fidelity not previously practical. In particular, developments in machine intelligence algorithms, numerical algorithms, parallel and massively parallel computers, clustered workstations, and scientific visualization provide the foundation for developing robust engineering tools for design diagnostics and analysis. One example is three-dimensional, time-dependent continuum mechanics predictive analyses based on first-principles models. Coupled with recent advancements in artificial intelligence and expert systems, these developments also make possible comprehensive systems analysis for plant management, control, and optimization — analysis that can supplant experimentation in some cases.

The first part of this initiative focuses on developing and implementing numerical methods on state-of-the-art parallel computers and workstation clusters. Significant effort also will be devoted (1) to advanced visualization technology, such as Argonne's CAVE virtual reality environment, with the objective of interpreting computed and measured data, and (2) to Internet-based communication that facilitates scientific collaboration at a distance. Specifically to be emphasized are computational fluid dynamics (CFD) and engineering mechanics, for both nuclear and nonnuclear applications. The nuclear CFD applications will support the Laboratory's initiative in Nuclear Technology Research and Development (see Section IV.B.1), in areas including core thermal hydraulics, steam generator performance, reactor safety, and advanced reactor design. Nonnuclear CFD applications will support the Laboratory's initiative in Advanced Transportation Technology in the area of vehicle thermal management and combustion analysis. In engineering mechanics applications, advanced computing and visualization technologies will support U.S. and international nuclear technology programs in pressure vessel and containment analysis and in the area of plant maintenance and construction. The initiative will also support the Laboratory's Advanced Transportation Technology program through development of programs in crashworthiness and manufacturing technologies for advanced materials.

The second part of this initiative will establish a Machine Intelligence Technical Center for R&D on machine reasoning, automated pattern recognition, and system modeling on the basis of learned input-output relationships, as applied to off-line intelligent computer-aided design and diagnostic tools and on-line supervisory systems for process plants. The R&D will use the artificial intelligence advanced computing techniques of artificial neural networks, expert systems, and fuzzy logic to develop automated advisory systems and control systems that interface with interactive knowledge databases. The databases will draw on Argonne's broad competencies in thermal hydraulic systems, material behavior, structural response, and nondestructive signal processing. Applications will focus on support systems for process plant operators, such as predictive maintenance systems and automated in-service inspection equipment. This initiative will be based on the Laboratory's current work in areas such as diagnostics for steam generator tubing in pressurized-water reactors and on-line diagnostics and management to address nuclear power plant transients. Collaborative projects with both universities and industry will be actively sought.

Resources required for this initiative are summarized in Table III.13. Funding for activities related to nuclear technology is sought from DOE-Nuclear Energy, Science and Technology (AF); funding for activities related to transportation technology is sought from DOE-Energy Efficiency and Renewable Energy and DOE-Science.

Table III.13 Advanced Modeling and Simulation for Engineering Applications ($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	0.7	1.0	1.5	2.0	2.0	2.0	2.0
Capital Equipment	-	0.2	0.5	0.5	0.5	0.5	0.5
Construction	-	-	-	-	-	-	-
Total	0.7	1.2	2.0	2.5	2.5	2.5	2.5
Direct Personnel	3.5	5.0	7.0	10.0	10.0	10.0	10.0

3. Environmental Technologies

a. Electrometallurgical Technology

Situation

The Department of Energy currently is responsible for approximately 2,700 metric tons of spent nuclear fuel in storage at several DOE sites (INEEL, Hanford, Savannah River, Oak Ridge, and others). One evaluation identified over 130 different types of fuel in this inventory, representing a wide variety of fuel forms and storage problems. Some fuels are stored in water basins where they are deteriorating to various degrees, and others are in temporary dry storage.

Until its spent fuel can be conditioned for final emplacement in a geologic repository, DOE plans to repackage the fuel and place it in stable dry storage. The total cost of interim storage and licensing for the many different types of spent fuel is expected to be very high. Moreover, final disposal of certain fuel types would remain problematic, because they are not amenable to efficient direct disposal. For example, some fuel types still contain highly enriched uranium, which can cause concerns about criticality in a repository. A portion of the DOE spent fuel cannot be disposed of directly because it is chemically reactive or pyrophoric and therefore may be prohibited from repository disposal by Nuclear Regulatory Commission regulation.

Development of a standard, cost-effective means of treating different kinds of DOE spent fuel would provide a prudent backup approach in case current plans for direct disposal are not successful. The electrometallurgical treatment process being developed at Argonne has the potential to meet these requirements. Use of this process would allow all of the spent fuel stored at INEEL and at Hanford, as well as all of the non-aluminum-matrix fuel in storage at the Savannah River Site, to be treated by one common method, producing two common high-level waste forms. One form is a ceramic waste containing most of the fission products in a ceramic material produced by hot-pressing a composite of boro-silicate glass and zeolite. The composition of this waste form is essentially invariant, regardless of the type of spent fuel processed. The other waste form is a metal alloy whose composition depends largely on the types of structural materials present in the fuel. Most DOE fuels are clad with stainless steel or zirconium alloy, resulting in a very stable metal waste form with an iron-zirconium alloy matrix.

A three-year demonstration project on treating EBR-II spent nuclear fuel was completed in 1999. All success criteria were met. Throughputs that were demonstrated exceeded the hurdle rates of 16 kilograms per month for driver fuel and 150 kilograms per month for blanket fuel. Both the composition and mass of recycle, waste, and product streams were measured. Predictability of the process was demonstrated, as both facility and equipment achieved satisfactory availability. As expected, safety risks and environmental impacts were well within regulatory limits.

The Department of Energy has completed an environmental impact statement for the treatment and management of all the Department's sodium-bonded spent nuclear fuel. The associated record of decision is expected to endorse the preferred alternative specified: electrometallurgical treatment of the complete inventory of EBR-II sodium-bonded fuel. The DOE decision relies on the favorable final report by a special committee of the National Research Council that reviewed the EBR-II fuel treatment demonstration and associated technology development.

Vision

Through treatment of EBR-II and other sodium-bonded spent fuel, Argonne will demonstrate that electrometallurgical technology is a cost-effective option that provides a viable backup for managing a significant fraction of DOE's spent nuclear fuel inventory.

Objectives

The most important near-term objective will be to implement the record of decision associated with the environmental impact statement for the treatment and management of sodium-bonded spent nuclear fuel. At a minimum, this implementation is expected to involve treatment of the EBR-II spent nuclear fuel. Ultimately, a processing rate of five metric tons per year must be achieved, including up to 0.6 tons of driver fuel.

Issues and Strategies

Pending the record of decision for the environmental impact statement, Argonne will perform needed facility maintenance and upgrades as waste form testing and qualification continue. Assuming a favorable record of decision, Argonne will scale up electrometallurgical processing rates from the demonstration rates to a total of 600 kilograms in the first year. The processing goal for the following year will be 2,000 kilograms of heavy metal. The capacity rate of 5 metric tons per year is to be reached in the third year.

An important issue associated with treatment of the full inventory of EBR-II spent fuel is continued development of the electrometallurgical treatment technology in order to achieve the throughput rates required for economical operation. Although the basic technology has been demonstrated, product losses and waste streams should be reduced, new equipment should be produced, and batch size optimization should be achieved. The cost of continued technology development will be a significant fraction of total costs during the first several years of operation.

Another issue is the schedule for waste form development. Waste form development and qualification will extend well into the schedule for treating EBR-II spent fuel, because licensing of the new waste forms for ultimate disposal in a repository requires completion of an extensive behavior characterization database, reflecting both short-term tests and long-term tests with actual radioactive wastes that will extend several more years. Nevertheless, tests with surrogate fission products and limited tests with actual radioactive waste forms will provide sufficient data at the end of the demonstration phase to allow informed technical judgments regarding the viability of the new waste forms.

b. EBR-II Termination

Situation

The EBR-II Termination program involves two major elements: (1) shutdown and closure of the EBR-II reactor plant and (2) demonstration of the treatment technology for EBR-II spent nuclear fuel to allow disposal in a geologic repository. The major activities in the program and their status are as follows:

EBR-II Reactor Plant

- Removal of fuel: Completed.
- Draining of sodium coolant: Completed for the secondary sodium system; pumping system for draining primary sodium installed and tested.
- Chemical reaction of sodium coolant: Sodium process facility completed and processing sodium coolant from the Fermi-1 reactor, following an extended shutdown.
- Chemical reaction of sodium remaining in the primary and secondary systems after draining: Engineering and testing in progress.
- Closure of reactor systems: Engineering and planning in progress.
- Closure of support systems: Several systems closed; engineering and planning in progress for the remainder.

EBR-II Spent Fuel Treatment

- Modification and operation of the Fuel Conditioning Facility (FCF): Operations with spent EBR-II fuel in progress.
- Demonstration of technical feasibility of application of electrometallurgical treatment: In progress.

The capabilities necessary to complete the EBR-II Termination Program successfully — including unique facilities and personnel — are in place. The key facilities are the FCF (for electrometallurgical treatment of EBR-II spent nuclear fuel), the Hot Fuel Examination Facility (HFEF; for ceramic waste form operations for fuel treatment), the Sodium Component Maintenance Shop (for receipt and cleaning of major components from the EBR-II reactor), the Sodium Processing Facility (for conversion of elemental sodium to a solid that is 70% sodium hydroxide), the Radioactive Scrap and Waste Facility (for interim storage of EBR-II spent fuel and waste form products from fuel treatment), and the Analytical Laboratory (for analysis of radioactive process samples). Engaged in the termination activities are staff who operated and maintained EBR-II over its 30 years of operation, staff who operated the hot cells (at the HFEF, FCF, and Analytical Laboratory), staff who provided technical and analytic support for operations and research programs at Argonne-West, and support staff in areas such as radiation protection, safeguards, and security. Closure of the EBR-II reactor requires most of the same capabilities as earlier activities.

Argonne's collaborators in the EBR-II Termination program have similar interests in the problems associated with closing other sodium-cooled reactors, such as the Fast Flux Test Facility (FFTF) on the Hanford reservation, the Fermi-1 reactor owned by Detroit Edison, and the SEFOR reactor owned by the University of Arkansas. Potential future collaborators include international partners in the United Kingdom, Kazakhstan, and France.

With assumed funding of approximately $80 million per year, the full scope of EBR-II Termination activities is projected to continue through 2002. Treatment of the remainder of the EBR-II fuel inventory is expected to be authorized and funded at approximately the same level (adjusted for inflation) through the planning period and beyond.

Mission

The primary mission of the EBR-II Termination program is to close the EBR-II plant with minimal hazards remaining for humans or the environment. In completing this mission, the technology for safely and efficiently closing a sodium-cooled reactor, including treatment of spent fuel for disposal, will be demonstrated.

The variability and efficiency of the fuel treatment process were demonstrated in FY 1999. Near-term objectives are (1) to complete processing of all EBR-II and Fermi-1 sodium by mid FY 2001 and (2) to complete closure of the EBR-II plant by mid FY 2002. Treatment of EBR-II fuel at full-capacity rates is to be achieved in FY 2002.

If successful, much of the technology developed in the EBR-II Termination program can be applied to the decommissioning of other sodium-cooled reactors. Detroit Edison is following a similar path in the decommissioning of the Fermi-1 reactor, and EBR-II technology will be used in the eventual decommissioning of the FFTF reactor. The BN-350 reactor in Kazakhstan is another probable application of EBR-II technology. In addition, the electrometallurgical treatment technology developed for EBR-II may be beneficially applied to a number of other spent fuels from DOE reactors whose disposal presents problems.

Objectives

Key milestones for the EBR-II Termination program are as follows:

- Processing of primary and secondary sodium from EBR-II and sodium from the Fermi-1 reactor will be completed by April 2001.
- The record of decision associated with the environmental impact statement for treatment of the remaining inventory of fuels of the EBR-II type is scheduled for April 2000.
- Closure of the EBR-II reactor systems will be completed by March 2002.

Goals

The primary goal of the EBR-II Termination program is to develop, demonstrate, and apply technology for closing sodium-cooled reactor systems safely and efficiently. A long-term goal is to explore the beneficial application of EBR-II technology to other U.S. reactor systems and associated fuels, taking full advantage of established Argonne capabilities.

Issues and Strategies

Reduced funding in FY 1999 and FY 2000 for the EBR-II Termination program has required both voluntary and involuntary reductions in force and has stretched remaining resources, making achievement of program milestones extremely difficult. Moreover, projected funding requirements for the program in FY 2001 exceed the DOE FY 2001 budget request to Congress by $6 million. Insufficient funding would lengthen schedules and increase overall costs in the long run.

A panel of the National Academy of Sciences periodically reviews progress and planning for the treatment of EBR-II spent fuel. Interim reports on progress have generally been favorable. The final report, which is also expected to be favorable, is to be issued in March 2000.

c. Radioactive and Mixed Waste Treatment Technologies

Situation

Many of DOE's highest-priority business goals depend directly on the Department's environmental program, specifically on the objectives of the DOE Office of Environmental Management (DOE-EM), which is working under a plan — *Accelerated Cleanup: Paths to Closure* — that specifies that cleanup of most DOE sites will be completed by 2006. Included in the plan is application of new technologies that have reached various stages of development, with support from the DOE-EM Office of Science and Technology. Nevertheless, despite extensive cleanup efforts and this planning, many DOE waste streams associated with weapons production are expected to require treatment beyond the coming decade. In addition, many high-level wastes, spent nuclear fuel, materials associated with plutonium disposition, and other special nuclear materials are expected to remain problematic. Beyond 2006, new science and technology will be needed to address these long-term concerns at DOE sites; the national laboratories must play an essential role in the development, demonstration, and implementation of that science and technology.

Planning by DOE has included both "contained wastes" and "uncontained wastes." The latter have interacted with the environment and will continue to cause problems in water, air, or soil or during waste handling and disposal. In the near term, optimized treatment for certain important nuclear material and mixed waste streams and for immiscible organic groundwater contamination will almost certainly remain problematic.

Argonne has demonstrated significant core capabilities in advanced environmental technologies, built on its broad competencies in nuclear technology and environmental science and technology; its existing nuclear facilities; and its extensive understanding of and experience in resolving complex environmental problems at sites of DOE, the Department of Defense, other federal agencies, and U.S. industry. Most notable are the Laboratory's capabilities in environmental R&D, especially in the effective integration of the full range of relevant basic sciences with complementary fields as diverse as economics, operations research, and computer applications, as well as the more traditionally complementary scientific and engineering fields. This integration of capabilities in environmental research, technology development and deployment, comprehensive assessment, and remediation applications is the basis for Argonne's continuing development of advanced environmental technologies tailored specifically to particular facilities and waste streams for many different types of customers.

Vision

Argonne will advance understanding of environmental problems and will develop technologies that allow cost-effective remediation or prevention of those problems for nuclear waste, mixed waste, and other contaminants.

Objectives

Argonne's work on advanced environmental technologies has the following central objectives:

- Develop technologies and facilities for treating mixed waste and nuclear materials.
- Develop superior waste forms and methods of testing and validating techniques for predicting performance.
- Develop innovative environmental technologies that exploit the state of the art in separation science, chemical interactions, and advanced materials.
- Integrate scientific research with field engineering experience and methodologies in order to develop cost-effective solutions to environmental problems.

Issues and Strategies

Development of advanced technologies for mixed waste treatment and for decontamination and decommissioning is a logical extension of Argonne's broad background in reactor technology. In mixed waste treatment, Argonne plans to continue to specialize in remote-handling operations, transuranics, waste form development, environmental process monitoring, and nonthermal treatment options.

Argonne-West already deals with significant amounts of remotely handled radioactive and mixed wastes, which are stored at its Radioactive Scrap and Waste Facility. These wastes require additional characterization, segregation, treatment, and repackaging. In addition, the Laboratory has a number of R&D projects that support (1) DOE's Mixed Waste Focus Area and Nuclear Materials Focus Area and (2) the Waste Isolation Pilot Plant (WIPP), including work on characterizing transuranic waste and experiments on gas generation. In future work, Argonne will integrate R&D with treatment of its own mixed waste.

The DOE Advanced Mixed Waste Treatment Project will result in construction of a private-sector facility to treat for subsequent disposal large volumes of the Department's contact-handled mixed waste now residing at INEEL. In addition, Argonne-West will construct a Remote Treatment Facility to deal with the remotely handled mixed waste now residing at INEEL. These two new facilities are part of the INEEL Site Treatment Plan and are necessary to fulfill the Federal Facilities Act/Consent Order and the 1995 Spent Fuel Settlement Agreement with the state of Idaho to remove mixed waste from the state by 2018. Both facilities will be able to treat other waste streams as well. Beyond building and operating the Remote Treatment Facility, Argonne can provide technical support for these activities through its Idaho facilities and through expertise at both its East and West sites in handling and processing transuranics. The Remote Treatment Facility at Argonne-West is discussed further as a major initiative in Section IV.C.3.

Development of superior waste forms and associated innovative technologies generally involves the integration of applied engineering, basic materials science, and basic chemical science. Development of stabilized waste forms is very important for solving problems associated with high-level and mixed waste.

During the last decade, Argonne has performed a wide range of R&D contributing to waste form development, including work on the electrometallurgical treatment of spent nuclear fuel, long-term and accelerated testing of high-level waste glasses and technical support to the Yucca Mountain Project, development of room-temperature setting of chemically bonded phosphate ceramic waste forms, studies of glass compositional envelopes for DOE-EM, definition of performance specifications for Hanford low-level wastes, and phosphate mineralization of actinides achieved by the measured addition of precipitating anions. Argonne will continue to support DOE programs such as the high-level waste repository and the WIPP. In addition, technical support will be provided to the DOE field offices and to site contractors at major sites charged with cleanup and waste management, such as Savannah River, Fernald, Rocky Flats, INEEL, and Hanford.

Through the Mixed Waste Focus Area, the Nuclear Materials Focus Area, and the Environmental Management Science Program, Argonne will also continue to support DOE-EM R&D aimed at long-term disposal of waste forms. This research centers around the physics and chemistry of surfaces and interfaces; development of new waste forms for "problem" wastes; and modeling, validation, and performance testing.

Argonne's major initiative in Environmental Nuclear Technology is discussed in Section IV.C.1. Included below is a programmatic initiative addressing the chemical reactivity and degradation behavior of spent nuclear fuel.

Argonne continues to play an important role in DOE-EM's environmental technology programs. DOE wastes containing radionuclides will remain a major issue well beyond 2006, justifying the development of better treatment technologies. Areas for future investigation include interactions of radioactive elements in various media and waste forms, extraction or separation of radioactive and hazardous chemicals and contaminants, characterization of DOE wastes and contaminants, and prediction and measurement of contaminant movement in and around DOE facilities. Argonne will continue to exploit its basic science programs and unique facilities, such as the Advanced Photon Source and the Intense Pulsed Neutron Source, in order to explore advanced innovative technologies serving environmental restoration and waste management at DOE sites.

Initiative: Chemical Reactivity and Degradation Behavior of Spent Nuclear Fuel

Argonne is proposing an initiative aimed at understanding the chemical reactivity and degradation behavior of DOE spent nuclear fuel and other nuclear materials during interim storage, treatment, and final geologic disposal. Throughout the DOE complex, metallic uranium spent nuclear fuel has corroded during storage and in some instances has caused environmental, safety, and health vulnerabilities because of the chemically reactive nature of the corrosion products. Under certain conditions, the reactive properties of uranium and the resulting uranium hydride promote pyrophoricity, which can lead to uncontrolled self-ignition during storage and handling. A complete understanding of the conditions leading to pyrophoricity is needed for continued safety in interim storage, handling, and eventual underground disposal in a geologic repository.

This initiative builds on a small research effort funded in FY 1997-FY 2000 by DOE-EM through the INEEL National Spent Nuclear Fuel Program. The initial investigation has focused on the oxidation kinetics and ignition behavior of uranium hydride. The proposed initiative will expand into the following areas:

- Oxidation and ignition behavior of uranium hydride for various levels of moisture and oxidant content
- Characterization and testing of EBR-II reactor fuel that has corroded during wet storage
- Corrosion and leach testing of various metallic spent nuclear fuels, including that from EBR-II, the Fermi-1 reactor, and a number of research reactors
- Oxidation and ignition behavior of uranium products from Argonne's electrometallurgical treatment process
- Oxidation and ignition testing of various plutonium-based metal products

Funding is sought from DOE-Environment, Safety, and Health and DOE-EM (EW). Required resources are summarized in Table III.14.

Table III.14 Chemical Reactivity and Degradation Behavior of Spent Nuclear Fuel
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	-	0.3	1.7	2.3	2.5	2.5	1.3
Capital Equipment	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-
Total	-	0.3	1.7	2.3	2.5	2.5	1.3
Direct Personnel	-	0.3	4.4	12.7	13.9	13.9	7.0

d. D&D Technology

Situation

Decontamination and decommissioning (D&D) of production and research reactors and nuclear manufacturing facilities represents a major challenge for DOE and the commercial nuclear industry. Over the next several decades, several hundreds of billions of dollars will be spent internationally to perform such D&D. Moreover, D&D of power reactors will be much more costly, and the deregulation of the electric utility industry is accelerating interest among utilities and regulators in all aspects of power reactor decommissioning. Problems associated with D&D include safe and effective dismantlement of contaminated and radioactive components; packaging, transportation, and disposal of waste; and recycling and reuse of material.

Argonne is uniquely positioned to assume a leadership role in the development and demonstration of D&D technologies. A number of the technologies already developed or under development at the Laboratory can be applied to or adapted for D&D applications, including advanced cutting technologies (such as lasers, water jets, and plasma arcs), effluent control technologies (such as filters for aerosols and dissolved contaminants), instrumentation, decontamination methods (both chemical and mechanical), and risk assessment methods. Moreover, D&D of a number of reactors and related facilities at the Laboratory is presently planned or is in progress. These facilities are prototypes of systems used commercially, and they therefore provide excellent test beds for the demonstration of D&D technologies under controlled laboratory conditions. Techniques demonstrated successfully can be transferred to industry for use domestically and internationally. Development and demonstration of new technologies are being pursued simultaneously with the D&D of Argonne facilities, so that work on Laboratory facilities can be completed on time, while more broadly applicable technologies are being pursued.

Argonne is building its D&D Technology Program on a strong foundation of extensive experience in nuclear and environmental work, recent success in applying D&D technologies, and valuable strategic partnerships. The Laboratory has experience with the D&D of many types of nuclear facilities, including reactors, hot cells, and facilities containing glove boxes. Argonne also has a long history of developing and deploying both nuclear and nonnuclear technologies, and it has played a leading role in this country's first technology demonstration program at a working D&D site, the CP-5 Large Scale Demonstration and Deployment Project. The Laboratory has been instrumental in developing risk-based analyses for recycle and release criteria and for transportation. Its RESRAD family of computer codes is widely used to evaluate doses and related risks to human health and the environment that result from exposure to radioactivity and chemically contaminated materials. Argonne has also developed cost-engineering models that have been used to validate cost estimates throughout the DOE complex and has performed analyses under the National Environmental Policy Act for a wide variety of projects.

Argonne is a member of the Strategic Alliance for Environmental Restoration, which directed the CP-5 Large Scale Demonstration and Deployment Project. Other members are Commonwealth Edison, Duke Engineering and Services, Florida International University, ICF-Kaiser, and 3M. Under the project, which began in January 1996 and lasted two years, 22 technologies were demonstrated. Elsewhere, Argonne is active in several international organizations involved in D&D and has initiated information exchange programs with the International Atomic Energy Agency (IAEA), Japan, Russia, and Chile.

Vision

To optimize the cost-effectiveness and safety of D&D operations, Argonne's D&D Technology Program will continue to advance the development, demonstration, and deployment of cost-saving D&D technologies and to develop and execute analyses of risk, safety, environmental impacts, and costs for DOE, other federal agencies, regulators, and the commercial sector. The program will also continue its contributions to D&D education through training, workshops, and personnel exchanges.

Goals

The main goals of Argonne's D&D Technology Program are the following:

- Provide substantive information on the use and value of D&D technologies for all end users.
- Use Argonne facilities scheduled for D&D as test beds for the development, testing, and deployment of new D&D technologies.

- Coordinate a team of specialists who, in turn, will coordinate the research, development, demonstration, and evaluation of D&D technologies in order to achieve cost-effective D&D for the DOE complex.

- Provide technical services and support in the areas of risk, safety, and cost analysis, as well as in planning and technology deployment.

- Provide D&D training and participate in informational and educational exchange both domestically and internationally, including support for D&D in the former Soviet Union.

- Work with the DOE Environmental Management Science Program to encourage basic research in areas that will benefit D&D technology.

Issues and Strategies

Key to the development of Argonne's D&D Technology Program is formation of strategic alliances among national laboratories, utilities, universities, D&D contractors, and technology developers and providers. Argonne will continue to pursue appropriate alliances, with special attention to working with nearby Commonwealth Edison, the nation's largest nuclear utility. In all its D&D technology efforts, Argonne is working closely with DOE-Chicago Operations. Internationally, Argonne will take advantage of the Laboratory's strong international research reactor program, which dates back to Argonne's design of research reactors and, more recently, to the design and implementation of proliferation-resistant fuels for research reactors.

A number of external and internal factors will influence the success of Argonne's D&D Technology Program. External factors include scheduling of D&D by DOE and utilities, effects of utility deregulation, and the availability of low-cost disposal sites for low-level nuclear waste. Internal factors include close integration of the Laboratory's diverse capabilities in technology and advanced technical services. Equally important is the formation of partnerships and strategic alliances with organizations outside the Laboratory.

Initiative: D&D Technology Program

The D&D of surplus nuclear facilities — such as nuclear reactors, hot cells, and accelerators — represents a major challenge for DOE, the commercial nuclear industry, and other owners of nuclear facilities. Deregulation of the U.S. electric power industry is bringing D&D to the forefront in economic planning by commercial utilities because of the major liabilities associated with surplus nuclear facilities. In recognition of the magnitude of these problems, Argonne has established a D&D Technology Program to address the needs of DOE, commercial utilities, Nuclear Regulatory Commission licensees, the international community, technology developers, and D&D-integrating contractors. The primary customer is DOE. Building on current Argonne capabilities, the program focuses on four D&D areas: operations, technology, technical services, and education. This initiative is still evolving.

Operations. Argonne's operations group is responsible for the safe and efficient D&D of surplus nuclear and radiological facilities on the Argonne-East site. In addition to research reactors, these include shutdown nuclear support facilities such as accelerators, hot cells, and glove boxes and facilities for waste handling and storage. D&D for Argonne-East is estimated to be an $80 million effort that will be completed in 2003. By the end of FY 1999, 7 of 13 identified projects were completed. The 7 completions include 3 research reactors, a hot cell facility for examination of spent fuel, a plutonium glove box facility, an accelerator facility, and a waste ion exchange facility. These completions, constituting approximately 60% of the total work scope, have created an experienced, highly qualified group of D&D specialists. In addition to completing D&D work at Argonne-East, this group embodies knowledge that will be very valuable beyond Argonne, in the areas of needs assessments, baseline technology evaluations, and field execution.

Technology. Argonne is uniquely positioned to provide valuable services to the DOE complex and the commercial nuclear industry on the basis of extensive experience gained through on-site operations, the CP-5 Large Scale Demonstration and Deployment Project, and participation in the

DOE-EM Accelerated Site Technology Deployment Program. This experience is particularly valuable as a guide to the Laboratory's development of innovative new D&D technologies and methodologies and as a means of evaluating those innovations. The goal is to take full advantage of Argonne's strong background in many relevant areas of R&D and of the opportunity to demonstrate and deploy the D&D innovations, in order to create a highly integrated process of developing, using, evaluating, and improving D&D. All organizations involved in D&D, including the private sector, will benefit.

Services. Work in technical services in the D&D Technology Program is based on the development and application of improved risk-based approaches to cleanup and release criteria, regulatory standards, and transportation guidelines for the shipment of radiological wastes generated by D&D. The program is refining cost engineering methods for D&D through model development and validation. These refinements will allow much more accurate determination of the liabilities associated with pending D&D, for the commercial sector as well as for DOE, and will allow identification of opportunities for large savings. More generally, on the basis of its strong foundation in operations and technology, Argonne is well positioned to participate in D&D planning throughout the DOE complex and beyond. Up-to-date knowledge of the full range of applicable D&D technologies will enable the D&D Technology Program to guide the selection and deployment of proven new technologies that reduce costs, shorten schedules, and improve safety. This program specializes in the development and application of cost-effective characterization techniques for identifying the operational and environmental hazards associated with a D&D project, allowing more accurate planning and cost estimation at the project's inception. The D&D Technology Program's expertise in operations and in risk and safety analyses is being used to aid the development of environmental protection, safety, and health standards for D&D projects.

Education. The growth in D&D within the DOE complex and the commercial sector is significant. To help participants cope with this growth, the D&D Technology Program is conducting a variety of education programs and activities, including D&D workshops and courses sponsored by DOE, IAEA, and other customers for planners, project managers, engineers, regulators, and other stakeholders. An active exchange program will stimulate new ideas and their beneficial application.

Resources required for this initiative are summarized in Table III.15. Funding will be sought from DOE-EM (EW, EX); DOE-Nuclear Energy, Science and Technology (AF); selected U.S. utilities; and international sponsors.

Table III.15 D&D Technology Program
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	7.0	7.5	8.0	8.0	8.0	8.0	8.0
Capital Equipment	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Construction	-	-	-	-	-	-	-
Total	8.0	8.5	9.0	9.0	9.0	9.0	9.0
Direct Personnel	32.0	35.0	38.0	38.0	38.0	38.0	38.0

e. Energy and Environmental Systems — Assessment, Information, and Technologies

Situation

Considerations related to the availability of energy resources and their use, particularly environmental impacts to Earth and its inhabitants, are increasingly controversial. Cost and public perceptions are often paramount. Informed resolution of these controversies — complicated by economic, security, social, and political concerns — requires effective analysis of a very challenging range of disparate technical information.

Further challenges arise because responsibilities relating to energy and the environment are spread widely across federal agencies. No single agency has a mandate to examine the full range of relevant issues. Consequently, coordination of federal programs and their effectiveness often suffer, especially as federal budgets tighten.

For decades, Argonne has created better solutions to energy and environmental problems by applying scientific methods, new and modified technologies, and innovative processes, often by assembling interdisciplinary teams of specialists and integrating diverse technical resources to solve problems through focused study and the use of unique research facilities. In conducting technology evaluations, a particular strength of the Laboratory is its merging of decision analysis, risk assessment, information sciences, and economic evaluations with the engineering specialties and the physical, biological, and social sciences that are more traditionally applied.

Argonne's strategic planning for solving energy and environmental problems is driven by the following national needs:

- The rapidly growing complexity of the energy system and the general complexity of energy and environmental issues demand a multidisciplinary, integrated approach to solutions.
- Environmental problems require cost-effective solutions that are acceptable to the public, but measurement of costs and benefits is often highly uncertain and controversial.
- The growing information glut facing all decision makers requires the development of better ways to capture, merge, and display critical information. Argonne's unique capabilities in advanced visualization, data management techniques, and spatial and geographic information systems can help to meet this need.
- Assuring the safety, reliability, and continuity of critical national infrastructures — telecommunications, energy systems, transportation networks, water supply systems, banking and finance systems, emergency services, and government operations — is a growing challenge facing both government and the private sector.
- Environmental issues increasingly require global analysis and internationally coordinated government policies in such areas as climate change, pollution remediation, and resource management.
- Restructuring of the electric system requires new approaches to reliability, environmental protection, and preparation for disruptions. At the same time, new environmental regulations require the development and adoption of advanced procedures and technologies.

Vision

Argonne will provide further national and international leadership in the creation of innovative and cost-effective solutions to energy and environmental problems, through the development of next-generation technologies; through the application of state-of-the-art techniques in assessment, risk analysis, and decision analysis; and through the transfer of these technologies and techniques to the private sector and others in the research community.

Objectives

Key objectives of Argonne's program in Energy and Environmental Systems include the following:

- Develop models, methodologies, and techniques for the analysis and assessment of advanced energy systems that will provide decision makers with more accurate information about the changing structure of the energy system, particularly the electric power system.
- Develop integrated environmental assessments, risk analyses, modeling techniques, and innovative information systems that benefit federal managers, policy makers, and private-sector businesses facing new regulatory environments.
- Apply these energy and environmental tools, techniques, and methodologies to issues of national concern, and transfer them to other researchers and to private-sector energy organizations to support improved decision making.
- Develop environmentally friendly technologies that enhance efficient energy use and promote environmental soundness, especially in the transportation, industrial, and utility sectors.
- Make available more widely — to DOE, federal, and private-sector sites — the benefits of Argonne's unique capabilities in

characterization, decontamination, remediation, restoration, and waste management.

- Develop new approaches that enhance the security of the nation's oil, gas, and electricity infrastructure, as well as related U.S. capabilities in emergency services, resource supply, transportation, and urban systems.
- Focus the Laboratory's multidisciplinary assessments on issues of global climate change and the management and use of energy resources.
- Expand international activities that address global climate change and environmental protection.

Issues and Strategies

Argonne has considerable strength in most scientific and technical areas related to energy and the environment. The Laboratory is well organized to integrate its multidisciplinary capabilities in research, development, and demonstration of new technologies. Recognition of these capabilities has allowed Argonne to solve a wide variety of real-world problems and to strengthen further its relationships with sponsors. Current challenges include finding innovative methodologies for analyzing energy and environmental problems (such as global climate change and restructuring of the electricity market) that cannot be addressed adequately with conventional techniques, identifying the many opportunities for beneficial external collaboration, and extending the Laboratory's capabilities more broadly.

Strategies for meeting these challenges include the following:

- Explore additional opportunities beyond DOE to apply the Laboratory's special capabilities to benefit the Departments of Defense, Agriculture, and the Interior; other federal agencies; state and municipal governments; nongovernmental organizations; and the private sector.
- Advance the Laboratory's frontier technical capabilities by developing more cost-effective solutions in such areas as site characterization, remediation, subsequent long-term stewardship, and monitoring of closed sites. Develop better techniques for evaluating, mitigating, and remediating environmental impacts. Exploit more extensively synergies and opportunities for collaboration among Argonne programs in site characterization, soil ecology, and phytoremediation.
- Combine innovative decision tools with field techniques to create applied environmental methodologies that are more effective. Tailor more cost-effective approaches to site cleanup and long-term stewardship through better site sampling strategies, better monitoring methodologies, and more flexible decision making based on rapid acquisition and evaluation of field data.
- Address emerging technical issues associated with long-term environmental stewardship at DOE and other federal facilities, especially those requiring extensive cleanup. See discussion of the major initiative Science and Technology for Environmental Stewardship in Section IV.C.2.
- Collaborate with urban community groups to increase the stock of energy-efficient buildings, including housing and schools; to return abandoned sites to use; and to design and implement next-generation modes of urban transportation. Integrate the application of Argonne techniques, technologies, tools, and training to foster the creation of more livable-wage urban jobs, to ease urban blight, and to support the renovation of urban infrastructure.
- Contribute to assuring the security of key U.S. infrastructure systems facing external threats such as natural and technological disasters and international terrorism. Focus on key system components for the transmission and distribution of electric power, oil, gas, and water, in work for the Departments of Commerce, Transportation, and Defense, as well as for the Environmental Protection Agency and DOE. Explore and expand opportunities to apply Argonne's special technologies and capabilities to enhance infrastructure security efforts by electric utilities and other private industry. See

discussion of the new major initiative Infrastructure Assurance in Section IV.D.2.

• Expand activities with international organizations and appropriate foreign governmental organizations in the analysis of international issues concerning energy and environmental systems, including global electric system restructuring, transnational energy system interconnections, global climate change, sustainable development, hazardous waste generation, and ecosystem management.

• Taking advantage of Argonne's strengths in high-performance computing and multidisciplinary domains, investigate the application of advanced techniques such as complex adaptive systems analysis and agent-based simulation to provide better decision making information in the rapidly changing, highly complex, nonlinear arena of energy and environmental issues.

4. National Security: Arms Control and Nonproliferation

Situation

Argonne's Arms Control and Nonproliferation program coordinates all Laboratory activities directed at reducing the threat to U.S. national security posed by nuclear, chemical, and biological weapons. With the end of the Cold War, the principal threat to U.S. national security changed from large-scale nuclear war to asymmetric conflicts and terrorist activities by subnational groups. The early focus on technical means to verify treaty compliance therefore shifted toward developing ways to limit the spread of weapons of mass destruction.

Among the most pressing problems facing the United States is the breakdown of systems for controlling nuclear materials in Russia and the newly independent states (NIS) that resulted from the dissolution of the former Soviet Union (FSU). The United States is one of several countries providing technical assistance to these nations to help improve their systems for control of nuclear materials.

Argonne's nonproliferation and national security programs, with an annual budget totaling approximately $15 million, include several significant components:

• The Reduced Enrichment for Research and Test Reactors (RERTR) program, which develops new fuels, targets, and analysis methods to enable research reactors throughout the world to replace their highly enriched uranium in fuel and targets with low-enriched uranium

• The Nuclear Material Protection, Control, and Accounting (MPC&A) program, which assists Russia and the NIS in upgrading their methods of protecting nuclear materials

• The Verification Technology program, which develops very sensitive and selective instruments to detect radiation and chemical and biological effluents that may indicate clandestine proliferation

• The Nuclear Export Control program, which provides technical assistance to DOE, including (1) assessments of proliferation risk associated with proposed exports of nuclear and nuclear-related dual-use material, equipment, and technologies, as well as (2) establishment of effective systems of export control in Russia and the NIS.

• Packaging and storage of nuclear materials from the BN-350 breeder reactor in Kazakhstan, which implements U.S. nonproliferation goals by improving the security of the plutonium in the BN-350 spent fuel and blanket assemblies.

• Shutdown of the BN-350 reactor, which further serves U.S. nonproliferation goals by ensuring that the BN-350 reactor can never again produce nuclear materials suitable for weapons.

Mission

By exploiting the technical and analytical expertise of Laboratory staff and the Laboratory's facilities for physical and biological research, Argonne supports the efforts of federal agencies to reduce threats to national security that would result from the proliferation of weapons of mass destruction. In addition, Argonne helps to implement associated U.S. policy initiatives.

Issues and Strategies

Argonne plans to integrate and increase its support for nuclear nonproliferation initiatives, particularly by exploiting the Laboratory's unique expertise in nuclear and sensor technologies. RERTR activities will involve extensive cooperation with Russia and more than 25 other countries. The Laboratory plans to develop a new process to produce molybdenum-99, an important medical radioisotope, without the use of highly enriched uranium. The Laboratory also plans to develop new instruments to detect the presence of chemical and biological weapons. Argonne expertise will be used to enhance the security of nuclear materials at additional sites in the FSU and also to reduce the availability of weapons-usable materials by reducing stockpiles of highly enriched uranium. Other activities will focus on developing spin-off projects related to the Laboratory's established MPC&A and training programs in Russia and the NIS. In Ukraine, Argonne staff have improved the physical security and accountancy for highly enriched uranium at research institutes. On the basis of its expertise in nuclear fuel management, the Laboratory has a technical leadership role in packaging and storing spent nuclear fuel at the BN-350 fast reactor in Kazakhstan so as to improve the material's proliferation resistance. In addition, Argonne was selected to serve as one of two lead laboratories for a proposed project to assist Russia with the design and construction of a dry storage facility for fuel awaiting reprocessing at Mayak. Many of these activities will benefit from direct interaction of Argonne personnel with key staff of the DOE Office of Nonproliferation and National Security.

A major initiative, Arms Control and Nonproliferation Technologies, is discussed in Section IV.D.1. This initiative proposes significant expansion of Argonne's work on the development, demonstration, and deployment of nuclear material safeguard technologies.

5. Collaborative R&D Partnerships

Situation

Over the past decade, Argonne's technology transfer program has reinforced the Laboratory's reputation as a reliable, productive partner for industry, as Argonne researchers have come to better understand the technical needs and working relationships of private companies. In recent years, pursuit of opportunities for technology transfer has been facilitated by a new *Prime Contract* for the operation of Argonne and by new mechanisms for establishing agreements with business firms. The R&D work conducted by the Laboratory in partnership with industry contributes strongly to DOE's strategic goals in the Department's business lines of (1) Science and Technology and (2) Energy Technology.

Mission and Vision

The mission and vision of Argonne's technology transfer program include five elements:

- Enhance the worldwide competitiveness of U.S. industry through cost-shared and reimbursable R&D performed by the Laboratory.
- Enhance the Laboratory's R&D programs and increase their funding through interactions with non-DOE government entities and with private institutions, including industry and academia.
- License valuable Laboratory intellectual property to enhance U.S. economic competitiveness, while providing a source of revenue for Laboratory use in compliance with the terms of the *Prime Contract*.
- Foster utilization of the Laboratory's R&D.
- Deliver and leverage a technology transfer program — including policies, processes, and results — that increases returns to the Laboratory and significantly contributes to the Laboratory's fulfillment of its mission and

strategic goals. To this end, (1) improve the Laboratory's technology transfer policies and processes and (2) increase programmatic and stakeholder satisfaction with the technology transfer program and the associated construction, delivery, and execution of technology transfer solutions.

Issues and Strategies

Numerous cooperative R&D agreements (CRADAs) are supported through programmatic activities, and Argonne is increasingly using work-for-others contracts for industrial agreements. Full funds-in CRADAs are also used to advantage to develop cooperative research partnerships, when DOE funding to support Laboratory effort is not available. Argonne continues to increase the precommercial R&D that it performs for private industry.

IV. Major Initiatives

This chapter describes Argonne's major initiatives. The broader programmatic and strategic context for these initiatives is given in Chapter III. The Laboratory's initiatives represent important opportunities to enhance U.S. research capabilities and to advance scientific understanding and engineering achievement across a wide range of disciplines. Pointing to the future, the initiatives presented below are rooted in Argonne's accomplishments and core competencies.

Several of the initiatives discussed in this chapter received funding in FY 2000. They are still treated as initiatives for planning purposes because they are in early stages of development, and their size and programmatic importance justify continued management attention. All funds received during FY 2000 are included in the resource tables in Chapter VI of this *Institutional Plan*. However, resources required for initiatives in years beyond FY 2000 are generally not included in those projections. Projected resource requirements for all initiatives include costs associated with protection of the environment and the health and safety of workers and the public.

Argonne carefully considers the implications of the National Environmental Policy Act (NEPA) for its scientific and technical initiatives, as early as it is reasonable to do so. For initiatives where NEPA implications are expected to be significant, the implications are discussed explicitly in this *Institutional Plan*.

The initiatives in this document are presented for consideration by the Department of Energy. Inclusion does not necessarily imply approval, or an intention to implement, by the Department.

The major Argonne initiatives in this chapter are presented in four groups, according to the DOE mission area to which they relate most closely:

- Science
  - Rare Isotope Accelerator
  - High-Throughput Systems for Biomolecular Research
  - Enabling Technologies Center for Advanced Computational Modeling
  - Nanosciences and Nanotechnology — Center for Nanoscale Materials
  - SNS Long-Wavelength Target Station
  - Fourth-Generation X-ray Source
  - Laboratory Complex for Biostructure Research
  - Synchrotron Environmental Science
- Energy
  - Nuclear Technology Research and Development
- Environmental Quality
  - Environmental Nuclear Technology
  - Science and Technology for Environmental Stewardship
  - Remote Treatment Facility at Argonne-West
- National Security
  - Arms Control and Nonproliferation Technologies
  - Infrastructure Assurance

Other Laboratory initiatives more closely related to research within a single program area are presented in Chapter III and are listed at the end of this chapter.

A. Science

1. Rare Isotope Accelerator

Opening of new frontiers for research in nuclear physics is expected through the acceleration of beams of unstable nuclei (rare isotopes). The first experiments conducted at existing accelerators, including the Argonne

Tandem-Linac Accelerator System (ATLAS), demonstrated convincingly that unique information becomes accessible. Critical information previously impossible to obtain includes (1) cross sections for astrophysical processes such as nucleosynthesis during and shortly after the Big Bang, energy-generating processes in stars, and heavy-element production via the r-process during supernova explosions; (2) qualitatively new and unexpected nuclear structure effects in nuclei far from stability, at their very limits of existence; and (3) completely new approaches to studies of nuclear decay, reactions, and structure. All of these opportunities have triggered considerable excitement in the scientific community worldwide.

Exploration at these new frontiers will require extension of today's technical capabilities and facilities. This need and its scientific basis have been discussed in various recent workshops and symposia. The needs are documented in the *Isospin Laboratory (ISL) White Paper* of 1991 and its 1995 update, prepared by the Isospin Laboratory group, a user community involving 400-500 scientists that supports construction of an appropriate facility in North America. Most importantly, the *1996 Long-Range Plan for Nuclear Physics*, prepared by the DOE-National Science Foundation Nuclear Science Advisory Committee (NSAC), gives highest priority to a rare isotope accelerator facility as the major new construction project for the field.

The scientific opportunities that would be pursued at such an advanced facility were discussed at a workshop held on July 30-August 1, 1997. The results were summarized in a white paper titled *Scientific Opportunities* (the "Columbus white paper"). Argonne has developed a facility concept that will achieve the physics goals set forth in the NSAC *Long-Range Plan* and the Columbus white paper. The concept is based on two accelerators. It uses a flexible approach for the primary production accelerator, which will be a high-power superconducting heavy-ion linac. The heavy-ion driver can deliver beams of any element from hydrogen to uranium, so a variety of production mechanisms can be used. One mechanism, heavy-ion fragmentation, can be used with a magnetic fragment separator and a new kind of fast gas catcher. This method is independent of the chemical properties of the exotic species being used. The Argonne approach also capitalizes on the capabilities of the Laboratory's existing state-of-the-art heavy-ion accelerator — ATLAS — as the postaccelerator. The recently completed uranium upgrade of ATLAS makes the accelerator unique in the world in its ability to provide intense, high-quality, continuous-wave (100% duty cycle), heavy-ion beams for all elements up to and including uranium. ATLAS has excellent transverse and longitudinal phase space properties, and it excels in beam transmission and timing characteristics. These capabilities are important for nuclear structure investigations and astrophysics experiments in which the beam quality requirements are especially stringent.

In January 2000, a subcommittee of NSAC — the ISOL Task Force — recommended development of an advanced rare isotope accelerator facility based on the Argonne concept. The facility is currently envisioned to cost approximately $500 million.

Argonne's Rare Isotope Accelerator initiative has the added advantage of allowing timely construction. Preliminary estimates of effort, time lines, and cost suggest that this major new facility can be constructed within three years, following approximately two years of detailed facility design. Required resources are specified in Table IV.1. Funding is being sought from the Nuclear Physics (KB-02) program.

Table IV.1 Rare Isotope Accelerator
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08
Costs									
Operating	0.6	1.5	3.0	3.0	3.0	4.0	4.0	6.0	10.0
Capital Equipment	-	-	-	-	-	5.0	10.0	15.0	15.0
Construction	-	-	-	25.0	53.0	113.0	118.0	113.0	68.0
Total	0.6	1.5	3.0	28.0	56.0	122.0	132.0	134.0	93.0
Direct Personnel	1.0	3.0	7.0	50.0	100.0	200.0	200.0	200.0	200.0

2. High-Throughput Systems for Biomolecular Research

At Argonne's Advanced Photon Source (APS), DOE has invested in the development of unique facilities for studies of protein structures. The Laboratory proposes to capitalize on this capability more fully through the initiative High-Throughput Systems for Biomolecular Research, which aims to increase dramatically the rate at which the structure and function of biomolecules are determined and to use the resulting knowledge to advance DOE missions in the biosciences. This multidisciplinary initiative — encompassing structural genomics, functional genomics, computational biology, and biomolecular design — will expand Argonne's dynamic ongoing programs in biological science and biotechnology and will address specific DOE interests in the areas of bioremediation, carbon sequestration, and biobased energy production.

The ultimate objective of this multidisciplinary initiative is to accelerate understanding of basic biochemical mechanisms through more productive application of both experimental and theoretical capabilities. The initial objective is to enhance dramatically the understanding and the application of the principles of protein folding. Understanding the basic nature of the folds within proteins will allow researchers to predict the three-dimensional structures of previously uncharacterized proteins by deduction from nucleic acid sequences made available through databases produced by the U.S. Human Genome Program and the DOE Microbial Genome Program. Knowledge of these protein structures will be instrumental in defining the biochemical and cellular functions of novel gene products. Such knowledge will enable modifications of protein functions for numerous applications, including bioremediation, industrial processes, and drug design.

The present initiative includes the development of (1) computational methods for analyzing genome data to select protein targets predicted to represent unique protein folds, (2) robotic manipulation of expression systems capable of producing large amounts of selected proteins, (3) automated high-throughput techniques for protein purification and crystallization, (4) X-ray crystallography facilities at the APS, (5) high-throughput proteomics for gene product characterization, (6) combinatorics for study of intermolecular interactions, (7) high-throughput biophysical and biochemical characterization of gene products, and (8) advanced computational methods for rapid refinement and modeling of structures. These activities will be developed through significant partnerships with mathematical and computational scientists, materials scientists, chemical and physical scientists, and engineers. Early efforts will focus on developing (1) an efficient strategy for integrating multiple biochemical and biophysical probes with X-ray crystallography and (2) small-angle scattering from noncrystalline specimens.

On the basis of these developments, Argonne is seeking to partner with the state of Illinois to establish an Accelerated Protein Crystallization Facility that will be integrated with a dedicated beamline at the APS. When fully operational, this facility will be capable of determining up to ten new macromolecular crystal structures every week, a rate of progress that will justify expanding the initiative into a major data collection effort. The facility's main focus will be rapid determination of protein structures by taking advantage of custom-designed robotics and other automated capabilities supporting molecular biology studies. Data collected will markedly improve protein engineering technology in the 21st century, both in terms of cost-effectiveness and breadth of application. No facility of this kind now exists anywhere in the world. In addition to supporting a major data collection effort, the Accelerated Protein Crystallization Facility will serve as a unique resource for other DOE projects, for initiatives of the National Institutes of Health, and for the needs of industry.

Argonne's multidisciplinary initiative in High-Throughput Systems for Biomolecular Research is designed to elicit support from federal agencies beyond DOE. Table IV.2 describes the overall resources required, including the efforts of computer scientists, environmental scientists, and APS staff, as well as the biologists at the center of the initiative, working in the area of structural genomics. Increased resources specified for FY 2002 through FY 2006 will support multiple Argonne research divisions and construction at the APS of the beamline required for the Accelerated

Protein Crystallization Facility. The large increase in resources from FY 2001 to FY 2002 reflects anticipated expansion of computational and engineering capabilities for this initiative. Activities in the areas of computation, engineering, and molecular biology related to determination of molecular structure and function are expected to continue growing into FY 2003. The increases in operating expenses and personnel in FY 2004 and FY 2005 include the addition of eight staff members to commission and run the new beamline. DOE funding will be sought from the Office of Basic Energy Sciences (DOE-BES; KC-03) and DOE-BER (KP-11).

Table IV.2 High-Throughput Systems for Biomolecular Research ($ in millions BA, personnel in FTE)[a]

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	1.8	6.8	8.6	9.2	10.3	10.9	11.5
Capital Equipment	0.1	0.1	0.7	0.4	0.4	0.4	0.4
Construction	-	-	-	5.0	4.6	-	-
Total	1.9	6.9	9.3	14.6	15.3	11.3	11.9
Direct Personnel	10.3	26.3	38.3	40.3	43.3	46.3	50.6

[a]Resource projections include new funding from sources other than the Office of Biological and Environmental Research.

3. Enabling Technologies Center for Advanced Computational Modeling

Argonne proposes an Enabling Technologies Center that will research, develop, and deploy the software, algorithms, and communication infrastructure needed for advanced simulation on terascale computers.

The Laboratory has a long history of success in providing high-performance computational software to the research community. Argonne led the way in that area with the development of numerical software packages such as PETSc (Portable, Extensible Toolkit for Scientific Computing); advanced visualization packages, such as vtk, that enable graphics in immersive virtual-reality environments; standards and portable reference software for message passing; portable, parallel input/output implementations; and high-level tools such as Globus for developing grid applications. Much of this seminal work has already been incorporated in vendor products.

The Laboratory has also been highly successful — particularly through the Grand Challenge Applications program — in demonstrating the potential impact of advanced computing science and computer systems on scientific problem solving. Support from the Grand Challenge program allowed Argonne to establish the Center for Computational Science and Technology and develop parallel methods that, for example, made possible the direct phase solution of atomic-resolution crystallographic data and enabled the largest electronic structure calculations of actinides ever attempted.

Argonne now proposes to take the next step — a bold new initiative in advanced computation that aims to develop a new generation of software that will exploit the extraordinary capabilities of terascale computers.

The need for revolutionary advances in computational software was emphasized recently both by the President's Advisory Committee on Information Technology in 1999 and by the National Workshop on Advanced Scientific Computing hosted in 1998 by the National Academy of Sciences. DOE has identified simulation science as one of its principal research objectives for the 21st century.

This initiative proposes that Argonne contribute in a major way to future DOE efforts in advanced computational modeling and simulation. The Laboratory's Enabling Technologies Center will comprise three components: (1) R&D to create and deploy a new generation of scientific simulation software suitable for terascale computers, (2) development and operation of a computational technology test bed for evaluating innovative computer technologies in support of advanced computational modeling, and (3) design of collaboration technologies to enable collective problem solving by geographically distributed groups of researchers.

Software development activities will focus on four key areas: (1) software tools (e.g., adaptive gridding and meshing tools), (2) distributed computing (e.g., for computational grids), (3) visualization (e.g., for real-time analysis and browsing of terabyte-sized data sets), and

(4) numerical libraries (including, for example, abstractions and common interfaces to enable interoperability of diverse tools in large-scale applications). Each area will require substantial new investments in computer science and applied mathematics.

Argonne's strategy for the development of enabling technologies will be based on scalable open-source software. Open-source tools (such as Linux and MPI) represent an increasingly popular approach that will enable the scientific community to easily obtain codes, methods, and libraries and to work together in tackling large-scale scientific problems. Scalability will ensure that new software can be executed both on small systems and on larger systems comprising thousands of nodes, without loss in performance. The Laboratory, long an advocate of scalability, recently began experimenting with an open-source Linux cluster. The initiative proposed here will heavily leverage that experience.

The second component of this initiative is operation of a large open-source test bed. The test bed will capitalize on the Laboratory's considerable expertise in experimental computer systems, expertise dating from the establishment of the Advanced Computing Research Facility in the early 1980s. The test bed will include innovative computer systems selected for their potential to extend the range of computational simulations to the terascale level or to decrease costs. Additional test bed resources will include advanced data storage facilities and wide-area networks providing the high speed and high bandwidth essential for distributed collaborative problem solving. The Argonne test bed will provide an excellent environment for exploring new simulation software and for evaluating new terascale computers as they become available. In addition, the test bed will be an ideal resource for Laboratory computer scientists working closely with applications scientists on initial simulations of scientific problems in such areas as regional climate change, combustion, and structural biology.

The third component of this initiative focuses on the development of collaborative technologies, in which Argonne has considerable expertise. For example, as part of the DOE2000 program, Laboratory researchers explored issues regarding shared scientific instrumentation, reliable tele-presence software, advanced numerical techniques, and collaborative data management tools. Significant scientific challenges remain, however. Research is needed on component architectures, better interfacing between toolkits, collaborative management tools for remote job submission and scheduling, and new paradigms for interoperability of collaboratory applications. These technologies will form the basis of "collaboratories" — research centers without walls — that enable researchers anywhere to interact as if they were physically collocated, sharing data, high-performance computing systems, and instrumentation.

Required resources for this initiative are specified in Table IV.3. Funding will be sought from the DOE Office of Mathematical, Information, and Computational Sciences (KJ-01).

Table IV.3 Enabling Technologies Center for Advanced Computational Modeling
($ in millions BA, personnel in FTE)[a]

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating[b]	2.5	10.0	15.0	20.0	24.0	28.0	30.0
Capital Equipment[c]	2.5	5.0	8.0	8.0	8.0	10.0	10.0
Construction	-	-	-	-	-	-	-
Total	5.0	14.0	23.0	28.0	32.0	38.0	40.0
Direct Personnel	12.0	45.0	85.0	115.0	130.0	150.0	150.0

[a]Costs specified in the table are incremental to the existing annual base funding of $5 million.

[b]R&D on computational science, enabling technologies, and applications.

[c]Computational resources.

4. Nanosciences and Nanotechnology — Center for Nanoscale Materials

A new industrial revolution is beginning, based on making structures "from the bottom up" on the nanoscale. Nanotechnology will allow design of smaller, more efficient versions of existing machines such as computers. Furthermore, new materials with new and exciting properties on the nanoscale will assuredly enable many other important advances that cannot be predicted today. Realizing these benefits depends on a national effort in nanosciences and nanotechnology research, in which Argonne is prepared to play a leading role.

Revolutions in materials and chemical sciences are being enabled by advances in nanofabrication, many of which arose from the semiconductor industry. When artificial structures become comparable in size to the length scales of physical phenomena (typically in the nanometer range), novel properties can result. Examples include higher critical currents in superconductors, greater remnant magnetic or electric fields in dots, increased mechanical strength and endurance in structures, and enhanced chemical reactivity and novel chemistry in clusters. Exciting practical applications — from higher-density memory, to chemical and biological sensors, to catalysts — depend on increased understanding and novel science. Development of these applications is poised to benefit from revolutions in techniques employing X-rays, microscopy, and micromachines.

Argonne is well positioned to contribute to national goals in nanosciences and nanotechnology. For example, the Laboratory developed new understandings of thin-film effects in superconductivity, magnetism, and ferroelectricity that are a basis for investigating the effects of confinement in lateral dimensions. The Laboratory's materials science program has already begun to make selected nanostructures at outside laboratories, supported by core funding, laboratory-directed projects, and a new initiative in complex systems for magnetic vortices in superconductors. Lacking is the infrastructure for nanofabrication and characterization that this initiative proposes to develop. These capabilities would be natural complements to Argonne's strong materials characterization infrastructure (including the APS, Intense Pulsed Neutron Source, and Electron Microscopy Center for Materials Research) and ongoing efforts in materials synthesis, processing, and modeling.

Argonne is developing intimate collaborations among its Materials Science, APS, and Chemistry divisions to create new X-ray techniques, including a state-of-the-art X-ray nanoprobe, for characterizing the structural properties of nanostructures. In combination with characterization of nanoproperties based on microscopy and microelectromechanical systems (MEMS), the Laboratory is planning to establish a unique facility for research on nanostructured materials.

Adequate infrastructure for nanotechnology is a major issue, not just for Argonne's program but also for the Chicago area and the Midwest. The Laboratory has begun efforts to bring together partners in the region to discuss a shared vision for nanotechnology infrastructure, including plans for a regional user facility. The resulting infrastructure could be an asset both regionally and nationally, and local partners include both universities and industry. (The National Nanofabrication Network of the National Science Foundation has no locations in the Midwest.)

Materials science and chemistry are closely coupled in this initiative. Materials science will focus on the physical patterning of nanostructures and the controlled synthesis of nanophases, while materials chemistry and chemical sciences will emphasize self-assembly. In the area of characterization, materials science emphasizes structure and physical properties, whereas chemical sciences emphasize spectroscopic analysis. In coordination with the APS and other facilities, Argonne will develop unique capabilities for fabricating and characterizing nanostructures. Nanoscale materials will be applied to DOE's mission areas within the Laboratory, and novel industrial applications will be sought with partners in the private sector.

This initiative emphasizes non-semiconductor materials, an area of broad interest at Argonne. Much of the Laboratory's work in materials science and chemistry already addresses questions relevant to nanoscience, and future valuable applications to DOE goals in energy and the environment are certain.

A particular interest of this initiative is MEMS. Designing normal laboratory experiments on the MEMS scale allows experimenters to measure the physical properties of nanostructures. For example, the magnetic moment of a nanomagnet can be measured by a micro-susceptometer. In most cases, such "experiments on a chip" require only microfabrication (on the scale of one micrometer), not nanoscale fabrication (10-100 nanometers). Infrastructure for MEMS fabrication already exists within the DOE laboratory system, for example at Sandia National

Laboratories, where Argonne is already collaborating. In addition, Argonne has developed special materials that could find practical applications in MEMS, especially ultrahard nanocrystalline diamond films.

High-throughput approaches will be employed to study nanostructured materials, including the use of (1) highly parallel methods for their synthesis and characterization and (2) real-time *in situ* techniques. Fortunately, nanopatterning lends itself well to this approach to high-efficiency parallel processing of material samples. The high brightness of the APS allows the use of X-ray microprobe techniques to determine the structure and composition of large numbers of material samples generated in short times. The final step in this new approach involves storing and analyzing a vast quantity of measurements on structure and properties and relating the measurements to theoretical models and desired technological functionality. This final step requires large-scale data processing and simulation that will use massively parallel computer clusters.

Similarly, understanding the deposition and processing conditions for nanostructured materials is critical for controlling their properties. Real-time *in situ* techniques for studying nanostructured material synthesis will take advantage of various on-line characterization techniques, including X-ray scattering and spectroscopy at the APS. An important advantage of using *in situ* X-ray techniques for process monitoring is that many combinations of processing parameters can be investigated in rapid succession on a single sample. The wide range of processes critical to the preparation of nanostructure materials that can be characterized efficiently in this way includes chemical vapor deposition, physical deposition, plasma etching, and electrochemical deposition and etching.

The administration's National Nanotechnology Initiative could allow DOE-BES to substantially intensify its effort in nanosciences, and Argonne is ideally suited to serve as a center for this activity. This Argonne initiative combines two earlier Laboratory initiatives: (1) Nanosciences and Nanotechnology and (2) Center for Combinatorial Materials Science and Technology. Both of the earlier initiatives required microfabrication and nanofabrication, and the two efforts are now being integrated. Valuable integration with the Laboratory's work in the biosciences and computer science is also anticipated.

This Argonne initiative will require investments in the following three complementary areas:

1. *New Tools for Nanofabrication.* Focused ion beam and electron beam lithography are essential tools for nanostructure fabrication. Equipment for etching, deposition, and other processes is also required. Since several of these tools do not exist elsewhere in the region, they will attract outside collaborators and potential partners. X-ray microprobes that utilize the brilliance of the APS will be developed. For other tools, such as MEMS, cooperative development and use of infrastructure at other nearby institutions may be desirable. Tools for visualizing nanostructures, especially microscopy (electron, scanned probe, and near-field optical), already exist or are being developed at the Laboratory.

2. *Infrastructure.* Nanostructures are much smaller than a speck of dust, so very clean conditions are needed during their fabrication. Clean rooms and related infrastructure must be developed.

3. *Personnel.* The Argonne staff already includes many of the researchers required for this initiative, and several of the Laboratory's core programs will naturally move in complementary directions. Nevertheless, many new staff members with special skills will be needed in areas such as lithography, advanced electron and optical microscopy, and ultrafast spectroscopy.

Resources required for this initiative are summarized in Table IV.4. Funding is sought from DOE-BES (KC-02), the state of Illinois, and other sources.

Table IV.4 Nanosciences and Nanotechnology — Center for Nanoscale Materials ($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	-	-	-	-	-	-	16.1
Capital Equipment	-	-	-	-	-	-	1.3
Construction	-	-	24.3	48.3	36.1	26.2	-
Total	-	-	24.3	48.3	36.1	26.2	17.4
Direct Personnel	-	-	34.0	38.0	45.0	60.0	65.0

5. SNS Long-Wavelength Target Station

The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory currently is the highest-priority construction project of DOE's Office of Science. Among six laboratories collaborating on this very large project, Argonne has lead responsibility for the development of instruments and has a lead advisory role for the development of target systems for the first SNS target station. The SNS instrumentation budget is currently $110 million (plus a contingency allowance).

At the SNS, adding a second target station to the one already planned would markedly increase the facility's scientific capabilities. In particular, there is a strong case for a second station optimized for the use of long-wavelength neutron scattering. This Long-Wavelength Target Station (LWTS) would add 18 beamlines to the total available at the SNS. The National Science Foundation (NSF) has indicated interest in supporting development of such a target station, and Argonne and Oak Ridge National Laboratory are leading a team that proposed to NSF a three-year, $4.4 million conceptual design effort starting in FY 2000. The first year was funded at $1.44 million. Argonne scientists will lead conceptual design for both the target systems and the instruments for the second SNS station.

Following completion of that conceptual design, Argonne plans to propose to NSF and SNS that it take a leadership role in the entire NSF-funded development and operation of the LWTS, working in close collaboration with the Oak Ridge SNS organization. For the station's instruments, that leadership would encompass design, construction, and operation; for target systems, collaboration with Oak Ridge and other national laboratories is expected to be more extensive. Benefits from Argonne's leadership would be based on the Laboratory's extensive expertise in pulsed-neutron instrumentation, target systems, and moderator systems, as well as its broad relationships with neutron source users from U.S. universities, which have grown during many years of successful, highly productive operations and enhancements at Argonne's Intense Pulsed Neutron Source (IPNS). Close partnership among universities and national laboratories will also be crucial to the success of the LWTS.

Argonne plans to focus its efforts in the near future toward four areas that will enhance the contributions the Laboratory can make to the LWTS and the SNS more generally and that will also enhance ongoing operations at the IPNS. The four areas are as follows:

- Periodic operation of IPNS at 15 hertz — half the normal 30-hertz repetition rate and comparable to the rate expected for the LWTS. Operation in this mode will provide, for the first time, pulsed neutron beams including significant quantities of cold neutrons with wavelengths up to approximately 20 angstroms. This effort at the IPNS will demonstrate the concept of this mode of operation (along with corresponding experimental capabilities) for the LWTS project and will allow exploration of new scientific opportunities for users of the IPNS and, eventually, the LWTS. Interesting issues that will receive immediate attention include magnetic scattering coupled with neutron beam polarization and ultrasmall-angle scattering. Exciting new opportunities for essentially all existing IPNS instruments are expected from operations in this mode. Early development of these opportunities at the IPNS will strengthen the scientific case for the eventual proposal to the NSF to develop and operate the LWTS.

- Use of neutron beam polarization and subsequent application for separation of magnetic and nuclear components in scattering profiles. These powerful techniques have greatest impact at long wavelengths, for which the LWTS will be optimized. The IPNS uses polarization for reflectometry but not other scattering techniques. Concerted development of polarization capabilities will significantly strengthen the case for developing the LWTS, and it is an excellent way for Argonne to contribute through its leadership role.

• Use of the World Wide Web for remote experiment control and neutron scattering data visualization and analysis. This capability is absolutely necessary for Argonne's proposed remote operation of instruments at the LWTS. Argonne intends to develop a collaboratory environment so that instrumentation scientists using the LWTS can participate remotely in neutron scattering experiments, whether they are located at Oak Ridge National Laboratory, Argonne, or a home institution elsewhere. Achieving this objective will require dramatic expansion of an Argonne project begun in FY 1998. Initial development of collaboratory capabilities at the IPNS will educate the user community about the full range of benefits achievable.

• Conceptual studies of key aspects of the target-moderator-reflector system, such as target material and joint optimization of the moderator and instruments, especially in relation to long-wavelength neutron scattering. The rich experience at IPNS from operation of low-temperature moderators will be a valuable starting point for studying optimization of the target-moderator-reflector system. Beamline optics and advanced concepts for area detectors are particularly critical for cold-neutron instrumentation. The extensive IPNS experience in designing and operating beamline components and area detectors, along with the highly reliable IPNS cold moderator systems, provides ideal qualifications for testing new optics devices, instrument concepts, and detector systems.

6. Fourth-Generation X-ray Source

During the past three decades, the brilliance of new X-ray sources has doubled every 10 months. Argonne's third-generation APS serves as a case in point, at 11 orders of magnitude brighter than a laboratory X-ray source. Since operation of the APS began in 1996, many exciting new discoveries have been made — some expected, others more surprising. Not foreseen was the extent of the impact that the APS would have on life sciences research. Also unforeseen were the windows on new science that would be opened by the coherence of the X-ray flux produced by APS undulators, even though that coherence is limited. A panel convened by the Basic Energy Sciences Advisory Committee predicts that further unforeseen advances will occur if a fourth-generation X-ray source based on a linac-driven free-electron laser (FEL) is built. The most exceptional advances from such an FEL X-ray source are expected to result from its unique coherence characteristics, which far exceed the limited coherence attainable by third-generation sources.

The physics and technology for a fourth-generation X-ray source rely on the phenomenon of self-amplified spontaneous emission (SASE) in an FEL driven by a high-current, high-brightness linac. In comparison with the APS, the unique X-ray characteristics achieved by the resulting user facility will include (1) a peak brilliance nine to ten orders of magnitude greater, (2) an average brilliance greater by a couple of orders of magnitude, (3) an X-ray pulse duration shorter by three orders of magnitude, and (4) an X-ray photon degeneracy greater by many orders of magnitude. These capabilities of an X-ray FEL will revolutionize X-ray science and its application across a broad range of science and technology.

Realizing these potential benefits will require solutions for a number of challenging developmental problems falling in the areas of electron guns, accelerators, magnetic devices, X-ray optics, metrology, and transfer of coherence to experiments. The FEL-based fourth-generation light source requires electron beams of subangstrom emittance and subpicosecond pulse length. Among the major R&D objectives that must be addressed to satisfy these requirements are (1) showing proof of principle for lasing action by SASE, (2) developing techniques to produce and control an electron beam with the necessary current density and stability, (3) developing a driver accelerator with appropriate beam parameters, (4) developing a long undulator to generate X-ray lasing, (5) creating optics capable of performing optimally with X-rays having the unique mix of properties characteristic of an FEL source, (6) understanding SASE FEL saturation properties in the context of experiments by facility users, and (7) understanding and developing experimental techniques that will allow the most effective use of such an X-ray source in various applications.

In recognition of the need to address these challenges before an FEL-based X-ray user facility is designed and constructed, a collaborative R&D program is proposed by Argonne, along with four sister national laboratories and a university — Brookhaven, Los Alamos, Lawrence Livermore, the Stanford Linear Accelerator Center (SLAC), and the University of California at Los Angeles. The proposed program takes advantage of the special capabilities and expertise of each participating institution. Argonne's central role rests on its access to the APS linac and its expertise in the areas of beam controls, undulators, and X-ray optics and experimental techniques. It is essential to develop the SASE concept fully with long-wavelength light before demonstrating it in the X-ray range. Argonne's low-energy undulator test line (LEUTL), an extension of the APS linac, is ideally suited for investigating SASE phenomena with light wavelengths of approximately 100-600 nanometers and for developing associated accelerator and photon technologies. The LEUTL is critical for exploring the conditions needed to produce coherent synchrotron radiation from a fourth-generation source.

Argonne plans to initiate investigations of the SASE process at wavelengths of 100-600 nanometers in the LEUTL facility. These efforts include design of an undulator and associated particle beam optics, design and testing of particle beam diagnostics, and theoretical investigations of techniques for longitudinal compression of a low-emittance electron beam. APS scientists plan to design and build a long undulator with integrated diagnostics and beam control for use in demonstrating the SASE principle at wavelengths shorter than 600 nanometers. This device, with its diagnostics, will be used to investigate the transfer of coherence through beamline optics and to identify any thermal problems arising from nanosecond photon pulses generated by an FEL. Successful construction of such an undulator will promote the development of instruments and techniques appropriate for measuring the extraordinary properties of radiation from an SASE FEL source. APS staff demonstrated SASE at 530 nanometers in December 1999, a milestone that will be the basis for work at shorter wavelengths.

The main linac at SLAC is capable of accelerating electrons to 14 gigaelectron volts, so it can be used to test the SASE concept in the X-ray range. Operation of a proposed new test facility at SLAC, the Linac Coherent Light Source (LCLS), will provide knowledge sufficient to conceptualize the fourth-generation X-ray user facility. Argonne plans to explore the shorter-wavelength X-ray range within the six-laboratory LCLS collaboration. The estimated cost of the LCLS test facility is about $150 million, and the construction period is expected to be three to four years. The proposed starting date for construction is FY 2003.

Research and development supporting construction of the LCLS test facility started in the latter half of FY 1999. For the six laboratories of the LCLS collaboration, the estimated annual cost over a three-year span is $1.5 million. LCLS construction is expected to begin in FY 2003. Taking advantage of expertise centered at the APS, Argonne will perform R&D on advanced electron beam compression, theoretical codes to specify undulator performance requirements, technology required to design a long (approximately 100-meter) undulator, optics to perform various functions with coherent X-ray beams, and FEL experimental techniques for the X-ray range.

The undulator for the LCLS test facility serves two interdependent purposes. First, it shapes the short-pulsed beam from the linac. Second, it generates and amplifies X-rays produced by this beam. Preliminary analysis shows that one of the best design choices for the undulator would be a permanent magnet structure with a period of about 2.4 centimeters and a peak field of 1.3 tesla. The early cost estimate for such a 100-meter-long device is about $30 million. Argonne plans to apply its unique experience to the design, construction, and operation of such undulators, as well as to the development of the photon and particle beam diagnostics needed by the LCLS facility. Argonne will make its greatest contribution to the LCLS test facility by developing the undulator system with its integrated photon and particle beam diagnostic capabilities.

An early experimental program to test the unique characteristics of the LCLS has been formulated. The success of the program depends totally on the performance of optics exposed to high-power coherent X-ray pulses lasting a few hundred femtoseconds. Argonne will also contribute to the development of X-ray optics that can transfer the beam's coherence to the experiments of a fourth-generation X-ray source user facility. The physics of intense, coherent X-rays interacting with matter has not yet been explored. Also deserving concerted attention are the new experimental opportunities in time-resolved imaging and nonlinear physics studies opened by a short pulse length, 100% beam coherence, and enormous peak brilliance. Argonne researchers will use the LCLS X-ray beam to develop the required optics, instrumentation, and beamlines. Inclusion of these activities in the LCLS construction project will require added funding of at least $15 million, by preliminary estimates. Required resources are described in Table IV.5. Funding is being sought from the DOE-BES (KC) program.

Table IV.5 Fourth-Generation X-ray Source
($ in millions BA, personnel in FTE)

	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
Costs								
Operating	0.2	1.0	2.1	3.0	3.8	4.2	4.4	4.8
Capital								
Equipment	0.4	16.0	22.0	34.0	14.0	0.4	0.5	0.5
Construction	-	-	-	-	-	-	-	-
Total	0.6	17.0	24.1	37.0	17.8	4.6	4.9	5.3
Direct Personnel	1.0	5.0	7.0	10.0	12.5	14.0	14.0	14.0

7. Laboratory Complex for Biostructure Research

The APS has in process four prospective collaborative access teams (CATs) that are planning research in the field of structural biology, specifically macromolecular crystallography. Full scientific proposals from all four have been accepted by the APS. Proposal acceptance, coupled with a guarantee of beamline funding, is required before a CAT can sign a memorandum of understanding (MOU) with the APS. The MOU assigns to the CAT a location on the experimental hall floor and commits the APS to provide adjacent laboratory and office space. However, APS currently has no laboratory and office space available to support these CATs and their work in the life sciences.

An interagency group involving the National Institutes of Health (NIH), DOE, and NSF has discussed the need for funding agencies to collectively support structural biology researchers at the APS. The urgent need for a laboratory complex to support these users was given the highest priority. Consistent with this interagency recommendation, NIH committed to provide half of the required construction funding for this complex in FY 2000. The balance of the project cost is to be borne by DOE-BER in FY 2001. This DOE funding is requested in the FY 2001 President's Budget submitted to Congress.

Joint funding by NIH and DOE-BER recognizes their respective responsibilities for structural biology research. (Construction of the APS facility and its beamlines represents a DOE-BES investment of nearly $1 billion; the annual operating budget of approximately $85 million is also provided by DOE-BES.)

The current timeline calls for the four CATs to be operational approximately two years after approval of the proposed funding. This schedule will allow the CATs to construct their beamlines in a timely manner that minimizes delays to their planned research programs.

The proposed laboratory/office module (LOM) is a one-story building having approximately 20,500 square feet of occupiable space. The LOM will contain 32 offices and 8 laboratories and will connect directly to the APS experiment hall. In addition to office and laboratory space, common facilities in the LOM will include a machine shop, a meeting room, two offices (for APS staff and for environmental protection, safety, and health support staff), a secure room for electronic communication bridges, rest rooms, and a break area. The building will also include a complete system for fire safety, public address, and telecommunications that is tied into existing APS systems. Parking for about 60 vehicles will also be provided.

Required resources are described in Table IV.6. Funding is sought from DOE-BER (KP).

Table IV.6 Laboratory Complex for Biostructure Research ($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	-	-	-	-	-	-	-
Capital Equipment	-	-	-	-	-	-	-
Construction	3.0	3.0	-	-	-	-	-
Total	3.0	3.0	-	-	-	-	-
Direct Personnel	-	-	-	-	-	-	-

8. Synchrotron Environmental Science

Environmental research is undergoing a technical revolution. Environmental scientists, who have long used the classical macroscale research methods of biology, chemistry, geology, and physics, are just beginning to apply the newer microscale research technologies in truly interdisciplinary studies. In the offing are immense benefits from applying recent advances in X-ray spectroscopy, scattering, and imaging. Research fields that will benefit range widely, including areas as diverse as determinations of chemical speciation and mineral-fluid interface structure in the environment, optimization of chemical sequestration technologies, and improved understanding of biotic processes in extreme environmental conditions.

Through establishment of a Center for Synchrotron Environmental Science, Argonne proposes to serve as a world leader in the application of synchrotron radiation to environmental research. The nucleus of the center will be the APS, the most powerful tool for environmental research ever developed. The APS promises to enable important fundamental progress in environmental research through the application of a powerful set of synchrotron X-ray techniques that have already been demonstrated at the APS and elsewhere. Available techniques include X-ray absorption spectroscopy, X-ray scattering, X-ray standing-wave imaging, X-ray fluorescence analysis, X-ray tomography, and X-ray microbeam applications. The great brilliance and high flux of the high-energy photons available at the APS make Argonne the logical location for the Center for Synchrotron Environmental Science.

The advance of environmental science demands an ever increasing knowledge of environmental processes at the submicron to angstrom scales. In April 1999, environmental scientists from academia, industry, and government laboratories attended the Synchrotron Environmental Science workshop held at Argonne in cooperation with the University of Notre Dame and Michigan State University. The strong consensus of the workshop was that the revolutionary nature of synchrotron environmental science techniques should be communicated much more pervasively to an environmental research community that has long focused on more traditional macroscale research methods.

Beyond just raising general awareness of the compelling benefits of synchrotron research technologies, this initiative will advance environmental science by developing advanced measurement techniques and increasing the availability of synchrotron facilities dedicated to the field. By providing expertise that encompasses both environmental science and productive experience with synchrotron techniques, Argonne will serve as both collaborator and facilitator for the larger research community.

The Center for Synchrotron Environmental Science will meet three clear strategic needs. The first and most important is to focus an expanded scientific capability on the many key questions in fundamental environmental research that can be addressed effectively with synchrotron methods. The second need is to create and sustain an expanded scientific capability by recruiting a critical mass of environmental scientists who use the synchrotron as one of their principal research tools. The final need is for improved instrumentation serving environmental applications of synchrotron radiation and for greater availability of suitable APS beamlines. Both the improved instrumentation and the increased beam time must be made readily accessible to environmental scientists.

Concomitant with these technical needs is the need to establish a versatile, collaborative network of synchrotron-using environmental scientists that extends broadly outside Argonne. This network will foster interdisciplinary collaborations and will also serve as an environmental science think tank. Already dubbed the Argonne Network for Synchrotron Work in Environmental Research (ANSWER), the network will serve as a liaison for developing interdisciplinary synchrotron environmental research at the APS and other synchrotron facilities and also for hosting regular international conferences.

Argonne research groups are already undertaking major projects at the forefront of synchrotron environmental science. These research projects utilize beam time at four APS collaborative access teams (BESSRC-CAT, MR-CAT, SRI-CAT, and GSECARS-CAT), as well as beam time at the National Synchrotron Light Source and the Stanford Synchrotron Radiation Laboratory. Substantially more access to APS beam time will clearly be required for the expanded scientific program envisioned in this initiative. Development of new beamline capabilities will be pursued through partnerships with other organizations having complementary research interests.

Demand for environmental research capability at the APS is already growing rapidly. For example, the GSECARS user program receives many more environmental research proposals than it can accommodate with available beam time. The April 1999 Synchrotron Environmental Science workshop strongly confirmed the growing shortage of beam time relative to worthy research proposals, despite the fact that the NSF and DOE-BES have already invested heavily in beamlines at GSECARS and BESSRC that serve geoscience and environmental science.

Resources envisioned for the Center for Synchrotron Environmental Science are described in Table IV.7. In addition to DOE-BES (KC) and the NSF, support will be sought from other DOE offices and federal agencies having significant environmental programs, as their researchers become more aware of the benefits of synchrotron radiation. Likely future sponsors include DOE-BER (KP), DOE-Environmental Management (EW, EX), the National Aeronautics and Space Administration, the Environmental Protection Agency, and the Department of Defense.

Table IV.7 Synchrotron Environmental Science
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	-	0.9	1.0	4.0	6.0	8.0	9.0
Capital Equipment	-	-	-	2.0	2.0	2.0	1.0
Construction	-	-	-	-	-	-	-
Total	-	0.9	1.0	6.0	8.0	10.0	10.0
Direct Personnel	-	4.5	6.5	12.0	12.0	20.0	20.0

B. Energy

1. Nuclear Technology Research and Development

Argonne proposes a major initiative in nuclear technology R&D. This initiative's primary objectives are to ensure that nuclear energy remains a viable option within the nation's energy mix and to improve the safety and proliferation resistance of nuclear systems worldwide.

The need for a major U.S. initiative in nuclear technology R&D is evident. The U.S. nuclear technology infrastructure, which once led the world, has been eroded seriously and could be lost altogether if present trends continue. Yet the United States has over 100 operating nuclear power plants that produce about 20% of its electric power. Worldwide, a large and growing demand for nuclear energy is projected, especially in China and other Asian countries. More nuclear energy is clearly needed to achieve goals for reducing carbon emissions and increasing environmental security. The United States needs a strong nuclear technology infrastructure to support safe and efficient operation of our current nuclear power plants, to promote improvements in nuclear safety and proliferation resistance worldwide, to make U.S. nuclear technology companies more competitive in world markets, and to maintain the scientific and technical leadership that enables the United States to effectively influence international affairs relating to nuclear power.

Argonne's qualifications to undertake a major U.S. initiative in nuclear technology R&D are unique. Throughout its history, spanning more than 50 years, Argonne has been the nation's key laboratory for development of nuclear power technology, from the early pioneering days through the recently terminated Integral Fast Reactor program. Argonne is the only remaining U.S. laboratory having expertise in all aspects of nuclear technology — reactor physics, safety, fuels and materials, and fuel cycle technologies — complemented by a full set of test facilities.

Under this initiative Argonne will pursue the following broad goals:

- Maintain a complete core competency in nuclear technology.
- Conduct research into innovative nuclear technologies and concepts.
- Support the continued safe and efficient operation of current nuclear power plants.
- Support bilateral and multilateral international R&D collaborations and safety improvement projects.
- Conduct education and training activities for U.S. and international participants.

Implementation of this initiative will involve both existing and new arrangements. Argonne will continue to participate in the Nuclear Energy Research Initiative (NERI), which emphasizes R&D on new technologies to address the key issues affecting the future of nuclear energy. From the first set of proposals submitted to NERI (in FY 1999), 11 projects involving Argonne were funded. Argonne is the lead institution for 5 and a collaborator in 6. Project subjects include innovative reactor design, advanced reactor fuels, advanced control concepts for innovative reactors, and fundamental science applicable to materials, corrosion, and waste management problems. In FY 2000, one new project will be initiated.

Argonne will also continue to operate DOE's International Nuclear Safety Center (INSC) and participate in the Soviet-Designed Reactor Safety Program (SDRSP). These international programs currently focus on Russia, Kazakhstan, and Ukraine (though the INSC concept was conceived to apply more broadly, to China for example). The U.S. INSC currently is carrying out eight joint R&D projects with the Russian INSC. Argonne's work for the SDRSP emphasizes coordination of in-depth safety analyses in Russia and Ukraine. An important part of future plans is training of personnel from countries of central and eastern Europe, from elsewhere in the former Soviet Union, and from other countries developing nuclear energy programs.

In addition to the ongoing international INSC and SDRSP programs, Argonne proposes a major role in DOE's proposed bilateral collaboration with Russia to address proliferation challenges posed by nuclear facilities and weapons-usable nuclear material in Russia. In particular, Argonne would participate in collaborative R&D on nuclear fuel cycle options that maximize technological barriers to proliferation and also incorporate features promoting safety, environmental protection, and favorable economics. Argonne would also participate in other program elements relating to management of spent fuel and nuclear waste; materials protection, control and accountancy; and spent fuel from research reactors.

As part of this initiative and in partnership with the Idaho National Engineering and Environmental Laboratory (INEEL), Argonne will implement the Nuclear Reactor Technology Lead Laboratory Charter of the DOE Office of Nuclear Energy, Science and Technology (DOE-NE). Under this charter, Argonne and INEEL will maintain world-class staff and key facilities for advanced nuclear reactor R&D, will continually evaluate and integrate the results of related research from diverse sources, will serve as a technical resource for DOE-NE decision making on future advanced reactor R&D, will generally stay abreast of reactor-related R&D in the United States and abroad, and will help DOE-NE organize national and international forums to address important issues. Major proposed activities for FY 2001 involve developing technology road maps for Generation-IV reactors, establishing user facilities for fuel and reactor technology R&D, providing technical input to DOE-NE policy development and program planning, and maintaining a Technical Integration Office to carry out lead laboratory functions.

Argonne's Nuclear Technology Research and Development initiative — whether implemented through NERI, the Nuclear Energy Plant Optimization Program, the INSC and SDRSP, the bilateral collaboration with Russia, or the lead-laboratory collaboration with INEEL — will encompass all areas of nuclear energy technology, with emphasis on the following:

- R&D on fuels that have improved proliferation resistance and are capable of extended burnup, for advanced commercial power reactors (including mixed-oxide fuels) and for advanced research and test reactors
- Materials research to address issues of reactor aging and life extension, as well as to support innovative reactor designs and applications, such as reactors cooled by heavy liquid metal
- R&D on reactor safety, to improve accident management technology, improve the safety of Soviet-designed reactors, and address safety issues associated with innovative reactor designs
- Advanced modeling and simulation, as well as other applications of advanced computing technologies, such as artificial intelligence and pattern recognition
- Advanced fuel cycles and waste management technologies

Primary support for this initiative will be sought from DOE-NE (AF). Support for other parts of the initiative will be sought from the Office of Nonproliferation and National Security, from other federal agencies (such as the Nuclear Regulatory Commission), from private sources (such as the Electric Power Research Institute), and from international sponsors. Required resources are summarized in Table IV.8.

Table IV.8 Nuclear Technology Research and Development ($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	9.4	14.5	16.5	18.0	19.5	19.5	19.5
Capital Equipment	-	0.5	0.5	1.0	1.5	1.5	1.5
Construction	-	-	-	-	-	-	-
Total	9.4	15.0	17.0	19.0	21.0	21.0	21.0
Direct Personnel	40.5	60.0	70.0	76.0	80.0	80.0	80.0

C. Environmental Quality

1. Environmental Nuclear Technology

The DOE Office of Environmental Management (DOE-EM) is working under a plan — *Accelerating Cleanup: Paths to Closure* — that focuses on cleaning up most DOE sites by 2006. The plan includes the application of new technologies researched over the past ten years (through support by the DOE-EM Office of Science and Technology), which are currently at various points along the development-and-demonstration pipeline. Despite ongoing cleanup efforts and activities planned for the next few years, many DOE waste streams associated with weapons production are expected to require treatment beyond 2006. Not slated for complete remediation or permanent disposal by 2006 under the DOE-EM plan are high-level wastes, spent nuclear fuel, materials associated with plutonium disposition, and other special nuclear materials. In addition, optimized treatment for certain mixed waste streams and immiscible organic groundwater contamination will almost certainly remain unresolved. New science and technology will have to be applied after 2006 to address long-term needs at DOE sites, and the national laboratories have an essential role to play in the development and implementation of that science and technology.

Argonne proposes an advanced environmental technology program that builds on the Laboratory's (1) existing broad capabilities in nuclear technology and environmental science and technology, (2) existing nuclear facilities, (3) extensive understanding of environmental problems at DOE sites, and (4) capabilities for integrating multiple scientific and technical disciplines. Building on these acknowledged competencies, Argonne will develop advanced environmental technologies tailored specifically to the needs of particular DOE facilities and waste streams.

The major thrust areas to be developed within the initiative are (1) technologies for treating radioactive and mixed waste and (2) waste form development.

Efforts on radioactive and mixed waste treatment are logical extensions of Argonne's broad background in reactor technology. The Laboratory specializes in remote handling operations and transuranics; facilities at Argonne-West are uniquely suited to such R&D.

Development of waste forms and innovative new technologies generally involves the integration of applied engineering, basic materials science, and basic chemical science. This work is very important for solving problems associated with high-level waste, mixed waste, and waste stabilization.

Argonne continues to play an important role in environmental technology programs for DOE-EM. Radionuclide-containing wastes produced by DOE will remain a major DOE issue beyond 2006, justifying the development of technologies that are less costly.

Resources required for this initiative are summarized in Table IV.9. Funding will be sought from DOE-EM (EW) and DOE-NE (AF).

Table IV.9 Environmental Nuclear Technology
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	-	10.0	12.0	12.0	15.0	18.0	18.0
Capital Equipment	-	1.0	2.0	2.0	-	-	-
Construction	-	-	-	-	-	-	-
Total	-	11.0	14.0	14.0	15.0	18.0	18.0
Direct Personnel	-	40.0	46.0	46.0	60.0	72.0	72.0

2. Science and Technology for Environmental Stewardship

Argonne proposes a program of research, development, and analysis to address emerging technical issues associated with environmental stewardship at DOE and other federal facilities, especially those requiring extensive cleanup. This initiative takes advantage of the Laboratory's capabilities and experience in several key areas of science and technology, including technologies for site restoration and for decontamination and decommissioning, engineered materials, sensors, monitoring systems, basic contaminant behavior, information management, advanced simulation, and risk assessment.

The terms "environmental stewardship" and "long-term stewardship" refer to the physical and institutional controls, information management, environmental monitoring, risk assessment, and other mechanisms needed to ensure, in both the short term and the long term, the protection of people and the environment following completion of cleanups at government facilities. The emergence of concern about stewardship reflects a broadening of the earlier federal preoccupation with short-term aspects of cleanups, particularly satisfying immediate public concerns and complying with environmental requirements. Increasingly, federal policy makers recognize the importance of monitoring over many decades the performance of remedies and the effects on human health and the environment from residual contamination after closure.

Realistic consideration of stewardship issues has begun only recently. In FY 2000, Congress requested that DOE report by October 2000 on the costs, risks, and issues associated with sites (or portions of sites) to be cleaned up by 2006. This site inventory will provide the first integrated estimate of DOE's long-term stewardship responsibilities. To date, much of the attention has been on policy and regulatory issues, such as amendments to cleanup statutes, creation of high-level task forces involving all stakeholders, and investigation of alternative funding schemes. Daunting technical issues that have so far received minimal attention include the following:

- Understanding and monitoring material deterioration in barriers and closure systems
- Managing and maintaining critical information systems to provide access for future generations
- Sensing and recording changes in site risks resulting from residual contamination over decades

These issues spawn myriad technical questions that require resolution, prior to and in conjunction with the establishment and implementation of policies governing environmental stewardship. So far, only limited attempts have been made to create the scientific and technological bases required to answer those questions. However, early in FY 2000, a reorganization of DOE-EM created within its Science and

Technology component the Office of Long-Term Stewardship. Development of innovative approaches and technologies, by the new office and other federal agencies, will aim particularly at reducing the costs of long-term stewardship while assuring that levels of risk are acceptable to the public.

Argonne's program in Science and Technology for Environmental Stewardship will include research in the areas of restoration technology, engineered materials, and sensors to address important stewardship issues. An example is the design of barriers, closure systems, and facilities remaining after D&D, to withstand deterioration and to incorporate innovative means for monitoring and maintenance. One new technology likely to be required is long-lived sensors that can be interrogated periodically over decades.

Argonne will also provide new approaches to designing the information management systems required for environmental stewardship. In addition to preserving the right kinds of information about a closed site and its contaminant residuals, the systems must be managed and maintained to assure access for present and future generations. Simulations of the behavior of barriers and contaminant residuals, updated as new data become available, might be important components of these information systems.

Environmental monitoring and risk assessment directly address issues of ultimate public concern. Systems of sensors and information processing will be needed to detect the potential migration of contaminants in and around closed sites. Systems monitoring site ecosystems must allow stewards to distinguish long-term natural changes in the ecosystem from changes related to residual contamination. Risks will be evaluated differently in future decades, so monitoring systems may need to allow consideration of environmental variables other than those that are commonly evaluated today.

Argonne's current expertise and capabilities provide the foundation for its future contributions as the focal point for developing, evaluating, and implementing new technologies and systematic approaches to better address the problems of environmental stewardship. Key capabilities lie in the areas of research on environmental processes, sensor development and deployment, technical information management, simulation, environmental monitoring, and risk assessment. In addition, Argonne will rely on experience and on a national perspective gained in federal cleanups throughout the country. As in the past, new technologies and approaches created by the Laboratory will be scientifically sound, cost-effective, and acceptable to the public.

This initiative will proceed initially on two fronts. The first will take advantage of Argonne's existing technical capabilities to address environmental stewardship needs that have already been identified. Ongoing investigations focus on the following areas:

- Development of a decisional process tool for evaluations of site stewardship
- Modeling for long-term risk management
- Web-accessible information management support for long-term stewardship
- Instrument and sensor concepts related to gas generated during natural attenuation of environmental contaminants, a near-infrared hyperspectral imaging system for chemical identification, and a radio frequency scanning system for use in the subsurface
- Metal cycling by biological processes in the vadose zone of Earth's crust

This research undoubtedly will benefit from data produced at DOE sites where the Laboratory already has experience and access. The second front will involve discussions with potential research sponsors at DOE, the Department of Defense, the Environmental Protection Agency, and other federal agencies to explore more fully the emerging problems of long-term stewardship that they face and the ways Argonne's capabilities can be marshaled to help solve these problems.

Resources that could be applied beneficially to this initiative are described in Table IV.10. Funding will be sought initially from DOE-EM (EW, EX); Environment, Safety, and Health (HC); and Science (KP-12, KP-13). Funding projected for later years includes resources from agencies beyond DOE.

Table IV.10 Science and Technology for Environmental Stewardship
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	3.0	4.0	7.0	10.0	13.0	15.0	17.0
Capital Equipment	0.1	0.2	0.3	0.4	0.5	0.5	0.5
Construction	-	-	-	-	-	-	-
Total	3.1	4.2	7.3	10.4	13.5	15.5	17.5
Direct Personnel	13.0	15.0	26.0	32.0	39.0	40.0	41.0

3. Remote Treatment Facility at Argonne-West

Argonne proposes construction of a Remote Treatment Facility (RTF) at Argonne-West to provide the infrastructure needed to carry out three missions important to DOE, the state of Idaho, and the national nuclear complex: (1) near-term management of wastes resulting from nuclear research conducted in earlier years at Argonne-West, (2) R&D to achieve nuclear energy and national security goals, and (3) R&D to achieve environmental technology goals. Specials needs in each of these three areas require that DOE operate facilities dedicated to the development, testing, and implementation of technologies and processes involving the remote handling of highly radio-active materials and the use of intense radiation sources. Argonne would operate the proposed RTF both to meet local waste management needs and as a national user facility for the development and testing of remote technologies. The RTF would be created economically by augmenting existing hot cell facilities at Argonne-West. Development of the RTF would include an addition to the present Hot Fuel Examination Facility (HFEF) and integration of existing HFEF support capabilities, such as analytic chemistry laboratories, into RTF operations.

The 1995 settlement agreement and consent order in the action "United States v. Batt" (the Batt Agreement) requires that DOE provide the treatment and preparation needed for all mixed waste located at INEEL and ship the waste out of the state of Idaho by 2018. To meet near-term commitments specified in the settlement agreement, the RTF must be operational by 2006.

Moreover, DOE must prepare a plan for developing treatment capacities and technologies for each facility at which the Department generates or stores mixed waste. This order is driven by requirements of the Resource Conservation and Recovery Act and the Federal Facilities Compliance Act. An implementation plan called the *INEEL Site Treatment Plan* provides for firm and enforceable actions to meet the order, including construction of the RTF.

The RTF is being designed to segregate, characterize, treat, and repackage remotely handled materials, because plans do not call for those materials to be handled for disposal or interim storage at the Advanced Mixed Waste Treatment Project that is to be constructed by BNFL, Inc. These remotely handled materials include mixed waste that has long been stored at Argonne-West in the Radioactive Scrap and Waste Facility (RSWF) and the Radioactive Sodium Storage Facility (RSSF).

The RSWF at Argonne-West contains quantities of spent nuclear fuel, transuranic waste, waste of greater than class C, and mixed waste. The Batt Agreement specifies that the RSWF inventory of transuranic waste be shipped to the Waste Isolation Pilot Plant (WIPP) by 2018. The waste currently is stored in 910 RSWF liners having diameters up to 24 inches. The physical size of these storage liners and other components requiring remote handling will necessitate a large staging area in order to segregate, characterize, and treat the waste in a manner that meets criteria for the disposal facility. A further consideration is that no treatment process or final storage location has yet been identified for greater-than-class-C waste. The RTF would be a natural candidate to lead the development of safe, effective, and practical solutions to the problems associated with greater-than-class-C waste.

The RSSF contains various sodium system cold traps that will require the capabilities proposed for the RTF. For example, the Primary Sodium System No. 2 nuclide trap of the Experimental Breeder Reactor-II is shielded with 5,700 pounds of lead and contains an estimated 165 curies of cesium-137 activity. These traps are large and bulky. Disposal will require a facility having large openings into shielded cells capable of alpha-particle containment and a large, open floor space for work on the traps. The RTF will be designed to accommodate these large containers in alpha-containment cells. It will include specialized equipment for separation of materials that are highly radioactive, chemically reactive, or both from clean and low-level structural and shielding materials; equipment for treating these highly radioactive constituents into acceptable waste forms; equipment for compacting low-level waste; and equipment for cleaning or purifying materials where reuse is feasible and economical.

Regarding remotely handled sodium-bearing waste from the RSWF and RSSF, it is possible that much of the sodium could be removed from more highly contaminated constituents and packaged in the RTF for treatment in Argonne's Sodium Processing Facility. In cases where it is more practical, *in situ* reaction of the sodium would be performed in the RTF. In such cases, the facility would have heaters to melt the sodium, as well as a nitrogen purge to avoid or control sodium reactions. After sodium is removed and highly radioactive materials are segregated, the RTF will prepare all mixed transuranic waste streams for long-term disposal.

In addition to the wastes stored at Argonne, 1,200 cubic meters of suspect remotely handled waste has to date been identified at INEEL's Radioactive Waste Management Complex (RWMC), including remotely handled mixed transuranic waste and remotely handled mixed low-level waste. These wastes are a subset of a total 65,000 cubic meters of stored transuranic wastes that are now on pads and in storage buildings at the RWMC. The proposed RTF is the only safe way that has been identified to treat these materials.

Equipment planned for the RTF includes the following:

- Segregation tables and storage units that will maintain separation of organic and inorganic materials (so that much of the waste at this stage, when properly segregated and characterized, can be packaged for direct disposal at the WIPP or at a low-level radioactive waste disposal facility)
- Cutting and sizing equipment for large pieces of metal and other materials
- Shredders and grinders that can facilitate higher-density encapsulation
- A microencapsulation station to stabilize waste that is 15-35% organics
- Inspection and characterization stations (requirements for which will depend heavily on how frequently tests are performed for waste characterization and to satisfy the Resource Conservation and Recovery Act and the Toxic Substances Control Act and will also be determined by the need to integrate capabilities with those of the HFEF and the Analytical Laboratory at Argonne-West)
- Equipment for receiving, preparing, and unloading over-the-road certified shipping casks containing materials requiring heavy shielding for protection of personnel
- Stations for disassembly processes
- Stations to package materials from any of the steps described above
- Examination equipment needed to complement or enhance that at the HFEF

Project planning dates for the RTF are as follows: (1) submit a conceptual design report in March 2001, (2) complete detailed design in March 2004, and (3) complete construction in March 2006. The resources needed to meet this schedule are described in Table IV.11. Funding is sought from DOE-NE (AF).

Table IV.11 Remote Treatment Facility at Argonne-West ($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	-	1.5	2.0	10.0	-	-	-
Capital Equipment	-	-	-	-	10.0	5.0	5.0
Construction	-	-	-	10.0	20.0	25.0	15.0
Total	-	1.5	2.0	20.0	30.0	30.0	20.0
Direct Personnel	-	3.0	5.0	50.0	50.0	50.0	30.0

D. National Security

1. Arms Control and Nonproliferation Technologies

Argonne proposes to expand significantly its activities related to the development, demonstration, and deployment of nuclear material safeguard technology. For DOE-Nonproliferation and National Security and DOE-EM, the Laboratory's established sponsors in these areas, this initiative addresses nondestructive assay of materials, monitoring and surveillance systems, and advanced software products. Argonne will also leverage its expertise in special nuclear material handling and physics, along with associated facilities and materials, to conduct process testing of related technologies developed at Argonne and elsewhere in the DOE complex. On the basis of identified national needs, the Laboratory will develop advanced material assay and analysis concepts for niche applications. Technology development initiatives will be tied to the Laboratory's unique physical resources, including nuclear materials, remote handling facilities, and ongoing nuclear technology projects. The broad applicability of these technologies creates a potential to also serve the Department of Defense, DOE-Fissile Materials Disposition, DOE-Defense Programs, and DOE-Civilian Radioactive Waste Management, as well as other federal agencies.

This Arms Control and Nonproliferation Technologies initiative is strongly leveraged with core Argonne programs, including those in spent nuclear fuel treatment, nuclear waste, arms control and nonproliferation, and facility operations. Synergies have been particularly important in the areas of (1) nuclear material and waste characterization and (2) nuclear technology development. The Laboratory's work in nuclear material safeguard technologies has exploited existing facilities and material resources. Benefits have been international. The work could be expanded to include additional nuclear material characterization, software products for international safeguards applications, and process testing of radiation measurement and nuclear material monitoring technologies.

Funding for this initiative will be sought from DOE-Nonproliferation and National Security (GC or GJ) and DOE-EM (EW). See Table IV.12.

Table IV.12 Arms Control and Nonproliferation Technologies ($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	2.0	3.5	3.5	3.5	3.5	3.5	3.5
Capital Equipment	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Construction	-	-	-	-	-	-	-
Total	2.5	4.0	4.0	4.0	4.0	4.0	4.0
Direct Personnel	5.0	8.0	8.0	8.0	8.0	8.0	8.0

2. Infrastructure Assurance

Argonne proposes to expand its current research, development, and analysis activities in the area of critical infrastructure assurance through its newly formed Infrastructure Assurance Center. The goal of this work for DOE and other federal agencies is to develop and apply innovative technologies, methodologies, and analytic tools for detecting, mitigating, and managing recovery from disruptions of critical national infrastructures, including cyber-based information systems. Argonne's technologies and capabilities are particularly relevant to the infrastructures for energy (electric power, oil, and natural gas), transportation, water supply, information and communications, and emergency services, which provide essential services underpinning our economy, national security, and social structure.

This initiative responds to the findings and recommendations of the President's Commission on Critical Infrastructure Protection and to Presidential Decision Directive 63 (PDD-63), which outlines key elements of U.S. policy on critical infrastructure protection. The initiative is also consistent with the strategic thrust of DOE's Office of Critical Infrastructure Protection, which was established in October 1999 to serve as the focal point for DOE's critical infrastructure protection activities. Under PDD-63, DOE is the lead federal agency for assuring the continuity and viability of the nation's critical energy infrastructures.

Argonne's long history of work related to infrastructure assurance — reinforced by more intensive work over the past five years for DOE, the President's Commission, the Department of Defense, and other government organizations — provides the foundation for this initiative. The Laboratory will expand its activities in the areas of vulnerability and risk assessment; energy and water systems analysis; nuclear, chemical, and biological agent detection; dispersion modeling and analysis; transportation network analysis; information management; infrastructure interdependence analysis; agent-based and complex adaptive systems modeling and simulation; decontamination and remediation; and emergency preparedness and consequence management.

Technologies and capabilities are needed in all of these areas to address the unprecedented range of physical and cyber threats to our critical infrastructures that can arise from natural, accidental, and deliberate causes. The Laboratory will particularly emphasize development of methodologies and tools to analyze the new vulnerabilities that have arisen because our infrastructures have become increasingly complex, automated, physically interconnected, and logically interdependent. Such research on interdependence has been designated high priority by the White House Office of Science and Technology Policy, and it is a cornerstone of DOE's long-term R&D program on critical infrastructure protection.

Resources required for this initiative are summarized in Table IV.13. Funding will be sought from the DOE Office of Critical Infrastructure Protection, the DOE Office of Nonproliferation and National Security, other DOE program offices, and other federal agencies.

Table IV.13 Infrastructure Assurance
($ in millions BA, personnel in FTE)

	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Costs							
Operating	8.0	9.0	12.0	15.0	15.0	15.0	15.0
Capital Equipment	-	0.1	0.1	0.1	0.1	0.1	0.1
Construction	-	-	-	-	-	-	-
Total	8.0	9.1	12.1	15.1	15.1	15.1	15.1
Direct Personnel	40.0	45.0	60.0	75.0	75.0	75.0	75.0

E. Programmatic Initiatives

The programmatic initiatives listed in Table IV.14 are grouped by DOE secretarial office. These initiatives, including their projected resource requirements, are discussed in context with the Laboratory's scientific and technical programs in the research area strategic plans of Chapter III.

Table IV.14 Programmatic Initiatives

Initiative	DOE Program	Page
Science		
Laterally Confined Nanomagnets	KC-02	21
National Transmission Electron Achromatic Microscope	KC-02	23
ATLAS Detector Software Development	KA-04	29
IPNS Enhancement	KC-02	32
Biochips and DNA	KP	38
Biochips for Fast Diagnostics and Discrimination of Multidrug-Resistant Tuberculosis Strains		39
Biobased Chemicals		40
Atmospheric Boundary Layer Experiments	KP	42
Advanced Transportation Technologies	KU, EE, ED	49
Nuclear Energy, Science and Technology		
Advanced Fuels Development	AF	51
Transient Testing at TREAT	AF	53
Materials Technology for Nuclear Power	AF	54
Post-Operation Evaluation of EBR-II Materials and Components	AF	55
Severe-Accident Management Technology	AF	56
Advanced Modeling and Simulation for Engineering Applications	AF	57
D&D Technology Program	AF	65
Environmental Management		
Chemical Reactivity and Degradation Behavior of Spent Nuclear Fuel	EW	63

V. Operations and Infrastructure Strategic Plan

This chapter's description of Argonne planning for operations and infrastructure is presented at two levels. The main body of the chapter comprises individual strategic plans for human resources; environment, safety, and health; site and facilities; security, export control, and counterintelligence; information management; communications, outreach, and community affairs; performance-based management; and productivity improvement and overhead cost reduction. The introductory discussion, also organized in strategic plan format, presents globally relevant perspectives on planning for the Laboratory's operations and infrastructure and summarizes salient aspects of the individual plans that follow.

Mission

Operations infrastructure and support activities are crucial to the achievement of Argonne's missions. Operations organizations work as partners with the Laboratory's R&D programs, providing cost-effective, customer-focused infrastructure and services that enable the creation of world-class science, technology, and service products. Maintaining this institutional environment and support structure requires effective and efficient accomplishment of the following major mission elements:

- Provide centralized administrative, business, and technical support to the Laboratory's science and technology programs.
- Develop and manage programs for the recruitment, development, and support of the Laboratory's human resources.
- Develop and manage programs that facilitate and support safety and health in the workplace.
- Provide environmental stewardship of the Laboratory site.
- Manage and operate the Laboratory's physical plant; upgrade general plant facilities or construct new facilities as required.

General Situation Analysis

Nationally, overall DOE funding of research programs has declined for the past several years; Argonne's funding has reflected that general trend. Because operations and infrastructure are supported as a charge to the total program funding received by the Laboratory, there is always a great incentive to reduce these overhead costs and still maintain the effectiveness and quality of operations and services. Every overhead dollar saved is an additional dollar of direct program funding.

The current incentivized, performance-based contract between DOE and the University of Chicago for the management and operation of Argonne — hereafter referred to as the *Prime Contract* — has ushered in a new era in the relationship between DOE and the Laboratory. The Laboratory has benefited particularly from increased flexibility in management practices. With strong collaboration and support from DOE-Chicago Operations and its Argonne Group, Argonne now has the opportunity to institute a variety of best business practices.

General Goals and Strategies

The overall goal of the Laboratory's operations infrastructure and support functions is to provide unique, high-value technical services to support science and technology programs, along with effective and efficient administrative, business, and operational services at the lowest possible cost, either from external suppliers or internally. The Laboratory is engaged in a strategy to increase the efficiency of its operations and support units while maintaining their effectiveness and quality.

Attracting, developing, and retaining world-class researchers and support personnel is a primary Argonne goal. The Laboratory helps its line managers pursue this goal in many ways, including training in supervisory skills and improved information systems in such areas as position description maintenance and job applicant tracking. Planning for human resources is discussed further in Section V.A.

Argonne has endorsed DOE's Integrated Safety Management (ISM) policy as an effective framework for characterizing the Laboratory's approach to environment, safety, and health (ES&H) management. Ultimate goals are zero injuries and zero adverse environmental impacts. Argonne monitors its progress toward excellence in ES&H performance by using pertinent indicators, along with evaluations and assessments. The ISM program reflects these efforts. The Laboratory devotes considerable effort to identifying opportunities to improve its ISM program and to implementing such improvements. Improvement of facilities and infrastructure is programmed in accordance with a prioritized management plan for ES&H and infrastructure. These activities demonstrate the Laboratory's continuing commitment to effective environmental stewardship and to safety and health management. Argonne planning for ES&H is discussed further in Section V.B.

Continuing Laboratory goals are the efficient use and maintenance of the physical plant and the replacement of inefficient and substandard facilities. The principal challenges facing both Argonne sites stem from normal aging of buildings and infrastructure and substantial needs for updating. For Argonne-East, the Laboratory has prepared an FY 2002 line-item funding request that will eliminate use of off-site leased space. Title II design has been completed for replacement facilities to increase efficiency in the receiving, storage, distribution, and shipping of materials and goods. Construction is scheduled for the third quarter of FY 2000. At Argonne-West, closure of the Experimental Breeder Reactor-II is scheduled for completion in March 2002. Also being planned is construction of a major hot cell facility to handle and process for disposal remotely handled mixed transuranic waste from both the Argonne site and the Idaho National Engineering and Environmental Laboratory. Site planning is discussed further in Section V.C.

Under no circumstances does Argonne allow the export or dissemination of technologies or information that is controlled or sensitive (classified or unclassified) where such actions are contrary to U.S. export control regulations or other federal restrictions. This kind of protection and control of information and technologies is integral to all Laboratory activities, and the Laboratory fully informs its staff about restrictions and requirements for authorization and clearance. The safeguards and security program for the two Argonne sites protects special nuclear material, sensitive information, employees, and the environment from threats of theft, diversion, sabotage, or malicious destruction. Planning and programs in the area of security, counter-intelligence, export control, and nonproliferation are discussed further in Section V.D.

Because of the importance of information management and its related infrastructure, Argonne manages both as integral parts of research programs and institutional resources. The Laboratory provides a wide range of central services to support — in both digital and traditional modes — the collection, creation, dissemination, and archiving of R&D and administrative information. Strategic planning, funding, and coordinated management for the Laboratory's information infrastructure and systems are addressed collaboratively through policy and planning bodies. To ensure that information infrastructure evolves as needed to support programmatic needs, Argonne leads or collaborates in various national initiatives in cyber security, networking, and telecommunications, particularly through pilot projects that test the applicability of new information technologies to DOE-funded R&D. National and other external networks interface with local Argonne networks, positioning the Laboratory as a major player in national networking initiatives. Planning for information management is discussed further in Section V.E.

Through constant two-way communications, Argonne takes special care to maintain close, positive relationships with its employees, the research community, local and national news media, the trade press, the broad national public, and members of the public living near the two Laboratory sites. The full range of Argonne planning for communications, outreach, and community affairs is discussed in Section V.F.

Argonne's *Prime Contract* provides objectives, measures, and expectations for the Laboratory that foster outstanding performance. The Laboratory's performance is measured in three areas: (1) science and technology, (2) critical operations, and (3) general operations. Ratings in science and technology are developed from appraisals by the DOE program offices that are major sponsors of Laboratory programs, as well as from peer reviews organized by the University of Chicago's Board of Governors for Argonne. For DOE's rating process for operations, self-assessment by the Laboratory serves as a cornerstone. Performance-based management at Argonne is discussed further in Section V.G.

A disciplined overhead management system has contributed significantly over the past several years to reducing Argonne's overhead cost ratio, which is a performance measure under the Laboratory's *Prime Contract*. Also providing crucial benchmarks are DOE's three high-level performance metrics, including average cost per full-time equivalent (FTE) research employee. Productivity improvement and overhead cost reduction at Argonne are discussed further in Section V.H.

A. Human Resources

Situation

The quality of technical staff is a primary determinant of the performance of an R&D laboratory. Argonne's success depends critically on its ability to employ, develop, and motivate creative scientists and engineers.

Argonne's Human Resources (HR) Department works in partnership with the Laboratory's program and operations organizations as its principal customers, to develop an understanding of their needs and to support their strategic objectives. HR policies, procedures, and programs affect the potential employee's decision to join the Laboratory, help shape the working environment for those making a career at Argonne, and contribute to the well-being of employees — even after they retire — through important benefits such as health insurance and retirement income.

Equal opportunity legislation and affirmative action plans have opened many doors in the United States for women, minorities, individuals with disabilities, and veterans. Increasingly, the changing nature of the workforce and the imperative to increase productivity have encouraged the nation's commitment to diversity. Argonne values the diverse cultural and ethnic backgrounds of its employees and strives to create an environment that capitalizes on these differences as one means of attaining a high-performance workforce.

The regulatory environment plays a major role in shaping the Laboratory's HR policies. HR staff understand the complexity and legal implications of federal and state legislation and provide special training for Laboratory managers when required.

Goals

The general goal of the human resource function is to create and carry out exemplary programs that attract, develop, compensate, and retain the highest-quality staff, while capitalizing on the Laboratory's rich heritage and cultural diversity. To achieve this end, HR management must be fully integrated with the Laboratory's overall strategy. Some specific goals are as follows:

- Directly link and integrate HR strategies with the strategic needs of division managers.
- Maintain a compensation policy that is competitive with policies at peer organizations and that rewards superior performance.
- Foster the commitment of managers at all levels to equal opportunity, affirmative action, and diversity.
- Increase the representation of women and minorities employed by the Laboratory and in the job applicant pool, especially for underutilized job groups identified in the Laboratory's *Affirmative Action Plan*.
- Give employees opportunities for professional growth.

- Improve the timeliness and effectiveness of HR-related communications, information flows, and work processes.
- Provide services that promote the well-being and productivity of Argonne employees.

Strategies

Maintenance of a competitive compensation structure is an important factor in the Laboratory's competition with private industry for critical talent. All components of compensation — base pay, merit increases, compensation supplements, and promotion-related increases — are managed as a coordinated whole, and each employee's compensation (apart from fringe benefits) is linked to achieved performance as evaluated under the Laboratory's appraisal process, which focuses on sustained performance and compensation relative to peers and the external market. The Laboratory will periodically review its performance management system to ensure that, in addition to reflecting employee performance accurately, it

- Incorporates best practices,
- Identifies exceptional contributions, and
- Identifies high-potential employees.

Argonne's success in recruiting and developing high-quality employees depends on attracting talented people. This success means recruiting the best and brightest, including people from diverse backgrounds. The Laboratory's strategic plan for diversity aims directly at vitalizing diversity as a continuous, pervasive managerial objective. In addition, because top scientific talent is found around the world, HR maintains a highly successful visa administration support function.

The key to implementing more effective strategic HR management is enhanced dialogue with the Laboratory's programmatic and operations division managers, particularly regarding opportunities to go beyond purely administrative HR functions. Techniques to be employed include regular formal surveys of managers, greater input from HR liaisons within the individual divisions, and more frequent dialogue with division managers. More participatory management coordination is expected to yield both better HR operations and greater willingness to take advantage of HR services.

During FY 2000, HR is developing a planning, measurement, and feedback tool based on the "balanced scorecard" concept. The balanced scorecard framework translates an organization's mission into a set of performance indicators in four areas: (1) customer, (2) financial, (3) learning and growth, and (4) internal business processes. The objective is sound data and facts to support HR business decisions. (Argonne's procurement department has already implemented this approach successfully.)

Argonne recognizes its responsibility to supplement the formal education of its employees with performance-enhancing training. Course offerings are based both on assessment of professional development needs and on compliance with DOE directives. Argonne offers courses on a wide range of subjects, including supervisory skills, team building, project management, presentation skills, and R&D proposal development.

To increase the effectiveness and quality of information flows at reduced costs, Argonne takes increasing advantage of new electronic alternatives to the extensive flows of information in paper documents traditionally associated with HR functions. For example, the Laboratory's systems for administering merit review and position descriptions allow programmatic divisions to manage staffing and compensation planning more effectively, with less direct involvement by the HR Department. The Laboratory's intranet provides electronic versions of the employee handbook, the HR policy and procedures manual, benefit plan descriptions, and information on the historical performance of retirement funds. Being planned are personal benefits statements, as well as the capability to respond to on-line surveys, to choose among alternative benefits programs, or simply to change an address.

Argonne's comprehensive health screening and health promotion programs focus on medical surveillance and emphasize prevention and the general physical and emotional well-being of employees. They also encourage rehabilitation and maximize recovery opportunities for those whose work has been interrupted by illness or disability. The Laboratory integrates its management of worker's compensation claims with HR policies, medical department interventions, ES&H guidelines, legal requirements, and activities serving the needs of the Laboratory's research and support divisions. The overall goal is to return the employee to productivity as quickly as possible, to the benefit of both the employee and the Laboratory. During FY 2000, the Laboratory's medical department will devote significant effort to DOE's Beryllium Worker Protection Program. Strong support for this program has been shown by the involvement of the Laboratory's director and by the solicitation of input from current and former workers.

B. Environment, Safety, and Health

Mission

The mission of Argonne's ES&H program is to ensure that all Laboratory activities are conducted within regulatory constraints and with minimal and measured adverse impacts.

Vision, Strategic Goals, Issues, and Objectives

Argonne continuously pursues the goals of zero injuries and zero adverse impacts to health and the environment. Pursuit of these objectives is based on (1) effective integration into the Laboratory's work processes of the principles and functions of safety and environmental management and (2) the active, knowledgeable, and mutually supportive participation of every individual at the Laboratory.

Indicators of performance — such as injuries, radiological exposures, and environmental releases — are tracked and used as bases for feedback, lessons learned, and continual improvement.

With regard to ES&H, one of the most important challenges facing Argonne is providing facilities and other work environments that are safe and that furthermore encourage proper safety attitudes by evidencing a respect for safety requirements. Proper safety attitudes are the basis for continual improvement in safe work execution.

Situation

The four basic components of Argonne's ES&H program are as follows:

- Policies and procedures that clearly establish the Laboratory's expectation that work will be conducted in a manner that protects the health and safety of workers and the public and also protects the environment
- Continual maintenance of employees' awareness of workplace hazards and hazard controls, through training and communications of many kinds
- Experts in a wide range of required disciplines (who are employed by the Laboratory's research divisions or by operations organizations such as the Argonne-East Environment, Safety, and Health Division; the Argonne-East Plant Facilities and Services Division; the Argonne-West Reactor Program Services Division; the Argonne-West Nuclear Technology Division; and the Laboratory's Office of Environment, Safety, Health, and Quality Assurance Oversight)
- Dedication to the philosophy of Integrated Safety Management (ISM) as specified in DOE's *Prime Contract* with the University of Chicago

Safety statistics indicate that Argonne is a safe place to work, and experience indicates that the Laboratory's operations have minimal environmental impacts. Moreover, operational advances enable ever-improving safety and environmental protection, based on the explicit attention of all Laboratory employees. The principles and core functions of ISM, when fully understood by employees and continually applied, serve to maintain employee attention to essential ES&H issues, goals, and ideas. Since its introduction to the Laboratory in 1997, Argonne has embraced the ISM philosophy and has carried out a process of awareness building and continuous improvement in application of ISM principles to all aspects of the Laboratory's work.

During FY 2000 Argonne underwent a combined Phase I and Phase II verification of its ISM system. The verification team recognized that the Laboratory has indeed implemented ISM in its day-to-day work activities. The team also specified needed further improvements. Argonne is committed to developing and implementing corrective actions in FY 2000 to address the issues identified by the verification team.

Among the strengths of Argonne's ES&H program is a diverse cadre of experts in the field application of hazards identification and mitigation. The resulting experience and understanding of Laboratory operations have allowed the Laboratory's ES&H program to incorporate incremental regulatory changes as they are promulgated. Limitations in the ES&H program are primarily due to resource constraints. Without additional resources, the program may have difficulty complying with the tighter regulatory changes anticipated in the future. The Laboratory will include recognized resource needs in its ongoing ESH&I (ES&H and infrastructure) management plan process.

The ES&H assessments conducted by Argonne, and also by DOE's Argonne Group, are based on the ISM guiding principles and core functions. The assessments consider a number of different functional safety and environmental focus areas. One recent example is an assessment of the Laboratory's contracting process, which found an implementation gap for contract work done on-site that does not involve construction. (Such service contract work includes a wide variety of activities, such as cleaning, repairing machinery, and maintaining scientific equipment.) To close the gap with ISM principles, the Laboratory developed a formal program that categorizes the risk of proposed work, analyzes job safety implications, improves definitions of work scope and the oversight of work, and ensures contract language reflecting the risks and job safety expectations.

In July 1999 the DOE Office of Enforcement and Investigation inspected Argonne-East for conformance with DOE nuclear safety requirements. As a result, DOE issued to Argonne a notice of violations. The following related corrective actions were undertaken by the Laboratory:

- Radiation surveys were performed or begun in a large number of uncontrolled storage locations to search for possible "legacy" contaminated materials. A plan and a schedule were developed to complete, by December 2000, a Laboratory-wide radiological search for such legacy materials.
- A sitewide stand-down was held so that all health physics personnel could participate in a lessons-learned meeting about the release of potentially contaminated materials.
- Chapters in the Argonne-East *ESH Manual* were revised to clarify requirements and to address pertinent issues, for example by requiring a use history for materials or equipment that are being considered for release and have areas inaccessible to survey.
- Employee awareness was reinforced through memos to radiation workers, sealed-source custodians, and health physics personnel regarding the changes to the *ESH Manual* chapters, the notice of violations, and the expectations of the Laboratory's radiological protection program.
- The interim laboratory director appointed three committees to evaluate (1) radiological survey processes, (2) the radiation work permit process, and (3) ES&H issues related to the process by which employees leave the Laboratory.

During 1999 the DOE Office of Enforcement and Investigation issued enforcement guidance supplements emphasizing that the requirements of 10 CFR 830.120 in the *Code of Federal Regulations* ("the QA Rule") apply to all radiological activities unless they are specifically excluded by the rule itself (as is accelerator-produced radiation, for example). Argonne is complying with this guidance. The requirements in the QA Rule are more open to interpretation than are those in 10 CFR 835 (the "Radiation Protection Rule"). It is generally believed that enforcement actions at Argonne will be based more on DOE's interpretation of the QA Rule than on the graded approach under which the Laboratory has been operating.

The Department of Energy now requires most of its contractor laboratories to participate in the Laboratory Accreditation Program for Radiobioassay. After several years of development, this program was formalized in FY 1997; final program documentation was issued in FY 1999.

Argonne-East applied for accreditation in FY 1997 and went through the various accreditation steps (including a formal on-site review) in FY 1998 and FY 1999. Accreditation was granted in FY 1999. This program is to be reviewed and renewed every three years; the next on-site review is anticipated in FY 2001.

In response to a criticality event at a Japanese fuel processing plant in late FY 1999, DOE directed that reviews of criticality safety programs across the DOE complex be completed in early FY 2000. Argonne performed a self-assessment with criteria provided by DOE. The self-assessment concluded that, although the Laboratory's criticality safety program was still generally effective, it showed signs of slow degradation. Significant concerns were identified at both the Laboratory-wide and facility levels. Corrective actions that were developed will be completed in FY 2000. The Laboratory's contractual performance expectations for FY 2001 and beyond are likely to include performance measures reflecting demonstrated improvement in its criticality safety program.

Fire safety and life safety for Argonne-East buildings have been major focal points throughout the 1990s, and they will continue to be so through 2005. The Laboratory's fire safety improvement program is now entering Phase IV, within which nearly all remaining life safety improvements are scheduled for completion. During 2002 the Laboratory plans to replace all remaining deficient building fire alarm systems. During 2003 the Laboratory plans to correct all hydraulic deficiencies in fire sprinkler systems required for life safety. In the concluding Phase V, which will begin during or after Phase IV, the Laboratory plans to correct remaining fire sprinkler hydraulic deficiencies, replace fire suppression systems that use ozone-depleting agents, and address remaining fire safety needs that could prevent property loss or interruption of operations.

Argonne-East recycled excess bulk quantities of alkali metals to suppliers in FY 1999, greatly reducing the site's inventory of excess hazardous materials. For facilities housing residual alkali metals, disposition plans will be formulated over the next several years. These plans will probably also address the long-term maintenance of experimental systems.

The Argonne-East environmental monitoring program was reviewed from the ground up during FY 1999 to determine its adequacy and needed changes. The review began by identifying sources of radioactivity and chemicals. Pathway analyses then determined a final list of potential pollutants and media to be monitored. The list was used to update the site's Environmental Monitoring Plan, and appropriate changes were implemented in the sampling and analysis portion of that program.

The environmental restoration program at Argonne-East includes remediation of numerous areas where both radiological contamination and chemical contamination have been found or are considered likely on the basis of the site's history. Remedial actions are conducted in compliance with the Laboratory's RCRA (Resource Conservation and Recovery Act) Part B permit, which requires corrective actions at all sites that have been used to process or dispose of waste materials at any time in the past. Starting in the early 1990s, prior to issuance of the Part B permit in late 1997, the Laboratory voluntarily undertook several remedial actions. Major actions already completed include closure and capping of the 800 area landfill; installation of leachate control systems, a groundwater migration barrier, and groundwater extraction systems at the 319 area landfill; installation of a groundwater collection system in the 317 area; treatment of contaminated soil in the 317 area by using zero-valent iron addition in a soil-mixing process; and deployment of a tree-based phytoremediation system in the 317 and 319 areas, designed to hydraulically contain and remediate contaminated groundwater. By the end of FY 2000 the Laboratory expects to have completed remediation of — or to have received a decision of "no further action for" — 38 of 57 pending items identified under the RCRA Part B Permit (i.e., 49 solid-waste management units [SWMUs], 5 areas of concern, and 3 non-SWMUs). Argonne is working very closely with the Illinois Environmental Protection Agency to complete remedial actions and establish long-term stewardship of the site's environment.

In addition to the remediation of waste sites, Argonne-East is conducting decontamination and decommissioning (D&D) activities for several reactors and other nuclear facilities, to allow alternate uses or to prepare for demolition.

Already completed are the D&D of several facilities, including the Experimental Boiling Water Reactor, the Building 212 glove boxes, the JANUS reactor, the ATSR reactor, and portions of the CP-5 Reactor and the 60-Inch Cyclotron. Alternative storage is needed for remotely handled low-level radioactive (transuranic) materials now housed in the 317 area vaults, which are scheduled for D&D over the next three years.

At Argonne-West the Federal Facility Agreement and Consent Order (FFA/CO) for the Idaho National Engineering and Environmental Laboratory (INEEL) establishes a procedural framework and a schedule for developing, prioritizing, implementing, and monitoring environmental management and remediation actions at INEEL in accordance with CERCLA (the Comprehensive Environmental Response, Compensation, and Liability Act), RCRA, and the Hazardous Waste Management Act. Waste Area Group 9 (WAG 9) at Argonne-West is one of the ten INEEL WAGs identified in the FFA/CO, which was signed by Region 10 of the U.S. Environmental Protection Agency, the Idaho Department of Health and Welfare, and DOE. The FFA/CO lists Operable Unit 9004 as the WAG 9 "comprehensive remedial investigation/feasibility study" This comprehensive record-of-decision document identifies 5 release sites for remedial action and 34 other release sites for no action, on the basis of risks to human health and the environment. A phytoremediation remedy was chosen to satisfy the requirements of both CERCLA and the FFA/CO.

For WAG-9, Argonne-West completed the *Remedial Decision/Remedial Action Work Plan,* which identifies major tasks required to meet the remediation goals defined in the record of decision. These major tasks include completion of a health and safety plan, a field sampling plan, and a planting plan required for the phytoremediation remedy, which will use specially selected plants to extract heavy metals and radionuclides from surface soil. The radionuclides and metals become concentrated in aboveground plant parts, which are then harvested and removed from the site. The initial Argonne-West field season in FY 1999 involved (1) planting (in the spring) a type of tree specially selected by pilot-scale testing and then (2) harvesting (in the fall). The harvested plants were baled and will be shipped to an approved off-site disposal facility. This approach directly supports the goals of waste minimization and pollution prevention.

In response to lessons learned and effective feedback from ISM activities and in compliance with the Price-Anderson Amendments Act, Argonne-West has developed and implemented the Database for Improvement Opportunity Tracking. This database system will help the Laboratory implement a proactive approach to complying with the Price-Anderson Amendments Act and develop a more effective ISM program that takes better advantage of feedback and lessons learned.

Strategies

Argonne monitors its own progress toward excellence in ES&H performance by using pertinent indicators. This important component of Argonne's ES&H program complements evaluations and assessments by DOE and regulatory agencies. Laboratory line management, assisted by central support and oversight organizations, conducts frequent monitoring, surveillance, and evaluation in the workplace to assess the implementation of safety practices and procedures. Argonne strives to achieve ever higher safety goals that exceed the performance levels of other DOE contractors and the Laboratory's own past performance. (Results of a number of recent assessments, both internal and external, are discussed above.)

Argonne uses a formal ESH&I process to identify and prioritize problems that require facility improvements for correction. A master list of building deficiencies captures results from ongoing facility condition surveys, from regular facility safety reviews, and from other management and independent assessments. This list serves both as input for the Laboratory's ESH&I management plan and as a maintenance planning aid. Laboratory management establishes a prioritized list of facility-related ESH&I projects for the current year and for the succeeding two years, regardless of project funding source.

Program Planning

On the basis of the various assessments undertaken at Argonne and the deficiencies and opportunities for improvement they identify, the Laboratory establishes corrective action plans. Modifications to these plans sometimes result from changing DOE guidance and direction in such directly funded activities as environmental restoration and D&D of contaminated facilities. The following paragraphs summarize some of the issues and plans that the Laboratory is currently addressing or will address in the near future.

Argonne-East is undertaking a number of improvements in the Job Hazard Questionnaire form that links required ES&H training courses to workplace hazards and some specific job duties. These improvements aim to provide further delineation of workplace hazards, clarification of job duties, and inclusion of additional pertinent information in the questionnaire. The questionnaire is to be combined with a second form, Physical and Functional Requirements, that is used by the Laboratory's Medical Department to evaluate occupational risks. This combining of forms will simplify and clarify the screening of job content for hazards, from the perspectives of both training and medical implications. The multifunctional review and updating of the questionnaire planned for FY 2000 will result in a new form and process for the Job Hazard Questionnaire that are fully up to date and consistent with all relevant regulatory training requirements.

In response to DOE's review of beryllium health effects at all its sites, the two Argonne sites reviewed their historical records to determine degrees of beryllium exposure, the size of the potentially exposed population, and the identities of affected workers. Because of the apparently extreme sensitivity of the human lung to beryllium, the Laboratory included in the review personnel who were associated with beryllium work and others but who did not themselves work directly with the material. According to the most conservative criteria, the number of beryllium workers at Argonne-East could be as high as 1,500. Argonne-East is developing a beryllium disease surveillance program that could include a number of long-retired employees. The surveillance program at Argonne-West includes 37 current workers.

Argonne's FY 1998 environmental vulnerability assessment includes the following remaining issues where action is under way but incomplete:

- Minor contamination of shallow groundwater and soil by tritium exists near the CP-5 Reactor. This contamination is being monitored pending a determination of whether cleanup is needed.
- At Argonne-West, no on-site disposal (other than that associated with settling ponds) has occurred. Previous spills and releases are fully documented in the *Comprehensive Remedial Investigation/Feasibility Study for Argonne National Laboratory-West Operable Unit 9-04 at the Idaho National Engineering and Environmental Laboratory*. The state of Idaho has approved the Laboratory's desired-alternative approaches to cleaning up all of these spills and releases.
- Several small radiological facilities could beneficially undergo D&D. Except for non-defense transuranic waste, there are ultimate disposal sites for all Argonne-East radioactive waste. Each of these minor vulnerabilities is being addressed in the long-term budget and ESH&I plans.
- Characterization of the geology and hydrogeology at Argonne-East has the objective of identifying all subsurface pathways for potential environmental releases. Studies of groundwater flows have included mapping bedrock surfaces, characterizing glacial till in some portions of the site, and using the Laboratory's QuickSite® system. This work, supplemented by additional focused studies, has allowed integration of information to fill data gaps. Data from the site's existing system of groundwater monitoring wells have been catalogued. Available information is not yet sufficient to ensure compliance with the corrective actions section of the RCRA Part B permit, but relevant knowledge of the site's geology and hydrology has been greatly strengthened and will be increased further by future studies.

- For its Illinois site, Argonne is developing a wetlands management program to coordinate responses to regulations and permit requirements. Activities will include delineation of requirements, monitoring, sampling, and cost management. The Laboratory has developed a management plan, including recommended actions, for two wetland areas near the Advanced Photon Source (APS). In FY 2000 Argonne-East will undertake wetlands restoration and replacement needed to accommodate a new APS user module. A long-term needs plan, including funding requirements, has also been prepared.
- Argonne-East must reroute or close building drains that inappropriately discharge directly to the environment through storm drainage systems.

Argonne-East is following an approved 1999 baseline for accelerating completion of its environmental restoration projects, which specifies completion of all planned actions by FY 2003 if funding is adequate. Once restoration projects are completed, operation and maintenance of installed environmental protection systems must continue for some years in order to address requirements of the Illinois Environmental Protection Agency and DOE. The source of funding for these activities past the FY 2003 completion of the program has not yet been identified. The annual cost has been estimated to be as high as $450,000.

New baselines for D&D projects at Argonne-East were established in FY 1999. Completion of work for the six surplus facilities remaining on the site's D&D roster is scheduled for FY 2003. The main focus in FY 2000-FY 2001 is completion of the CP-5 Reactor D&D project and initiation in FY 2000 of the 60-Inch Cyclotron D&D project, with completion the following year. In FY 2001, D&D field work will begin on the Juggernaut Reactor, the Building 310 retention tanks, and the Building 301 hot cells. Field work on the ZPR 6 and 9 Reactor D&D project is scheduled for FY 2002. Needs beyond those identified in the baseline funding plan are under discussion.

C. Site and Facilities

Situation

Argonne National Laboratory conducts basic and technology-directed research at two sites owned by DOE. Argonne-East is located on a 1,500-acre site in DuPage County, Illinois, about 25 miles southwest of Chicago. Argonne-West, located on an 800-acre tract within INEEL, about 35 miles west of Idaho Falls, Idaho, is devoted mainly to R&D on nuclear technologies and nuclear environmental management.

Argonne-East contains 4.8 million square feet of floor space, which includes 100,000 square feet of leased external commercial space. The estimated current plant replacement value is approximately $1.8 billion. Argonne-West contains 581,000 square feet of floor space, with an estimated replacement value of $400 million. Space at Argonne-East, which accommodates roughly 5,200 persons (including DOE employees, contractor personnel, and guest or user personnel), is more than 98% occupied. Argonne-West accommodates about 800 persons.

The principal challenges facing both Argonne sites stem from normal aging of buildings and infrastructure and substantial needs for updating. Excluding facilities at the APS, more than 85% of Argonne-East buildings are more than 30 years old; almost half are over 40 years old, as is much of the site's supporting infrastructure. As reported to DOE through the FIMS (Facilities Information Management System) database, aging of these facilities, coupled with increasingly tight funding, has led to significant backlogs of maintenance, repair, and modernization needs. Approximately 38% of occupied Argonne-East facilities need major rehabilitation or upgrades. Substandard facilities (representing 6% of total floor space) require replacement. Some of the facilities require partial D&D to make space available for future programs or to comply with environmental regulations. Certain of these facilities should be demolished after D&D, because the Laboratory could not reuse them efficiently. Utility systems at Argonne-East generally have adequate capacity for anticipated requirements, though some upgrades are needed for compliance with standards and increased reliability. At Argonne-West, recent renovations and continuing maintenance of major facilities are enabling pursuit of important DOE nuclear technology programs.

Supplement 3 of this document includes more detailed discussions of plans for Argonne's two sites and their facilities.

Mission and Goals

Argonne's sites and facilities support the execution of world-class basic research and technology-directed research by providing reliable, efficient, cost-effective facilities offering work environments that are safe, healthful, and environmentally sound and that generally stimulate creativity and high productivity.

General goals are to improve effective use of existing facilities, to upgrade strategic facilities and infrastructure, and to eliminate substandard facilities.

Strategies

Argonne-East has managed its available building space very aggressively, particularly by employing a space use charge-back system. This incentive motivates efficient use of space and allows removal of large amounts of substandard space. Demolition of substandard buildings and temporary trailers reduces operating and maintenance expenses, including the cost of purchased energy, and also eliminates unsightly areas. Many cleared sites have already been restored and made available for future Laboratory facilities. The Laboratory is preparing an FY 2002 line-item funding request that will eliminate the remaining use of nearby off-site leased space.

At Argonne-West, program sponsors other than DOE-Nuclear Energy are charged for facility utilization in a manner similar to the space use charge-back system at Argonne-East. Site services such as fire protection and dosimetry are purchased from the INEEL site contractor.

Argonne manages its assets in consonance with the Life Cycle Asset Management process. More generally, the Laboratory's formal planning processes have the flexibility to accommodate changing missions and directives. Both Argonne sites maintain long-range plans for needed facilities upgrades and for infrastructure rehabilitation. Energy conservation and cost reduction are priorities; strategies being pursued to further reduce energy consumption and associated costs include energy savings performance contracting.

Argonne-East regularly uses a Condition Assessment Survey to evaluate the baseline condition of all facilities. The site has an on-line system for maintenance control and reporting that facilitates better planning of work, tighter control of resources, and more accurate measurement of results.

Argonne-East has upgraded or revitalized several strategic buildings, utility systems, and other infrastructure over the years to accommodate new initiatives, increase ES&H acceptability, increase reliability, save energy, and replace obsolete building systems that require excessive maintenance.

In the past, fragmentation of funding sources has hampered efforts at Argonne-East to integrate facilities needs efficiently and to manage the site's infrastructure generally. The Laboratory's strategy for coping with these difficulties is a stakeholder-based process that annually produces databases characterizing Laboratory-wide physical plant needs, including a single integrated list of all ES&H projects. The list, which characterizes the risks to be addressed by both unfunded and funded projects, is the basis for management decisions regarding prioritization of efforts, allocation of existing resources, and development of additional funding proposals.

Argonne-East is designing replacement facilities to increase the efficiency of its receiving, storage, distribution, and shipping of materials and goods (for both intrasite shipments and those crossing the Laboratory's boundaries), as well as to facilitate removal of the last cluster of outmoded Quonset huts and their supporting facilities. This design effort will provide a baseline for considering the cost-effectiveness of environmentally sensitive construction technologies such as maximizing the use of recyclable materials. Further plans call for replacement and removal of temporary modular office facilities on the site and the rehabilitation or upgrading of other facilities and infrastructure. High priority is also attached to continuation of ongoing projects for life safety, environmental remediation, and D&D of closed facilities such as reactors and hot cells.

Historically, Argonne has received insufficient capital funds to rehabilitate, modernize, and preserve existing facilities. Several DOE programs provide capital funding: general plant projects, general purpose equipment, Multiprogram Energy Laboratories — Facilities Support, and Environmental Management. This DOE funding allows the Laboratory to address its most urgent needs to upgrade the physical plant, meet safety and environmental standards, and decontaminate facilities. Particularly needed are additional funds for general purpose equipment and plant rehabilitation, in order to offset the normal effects of aging, to accommodate evolving scientific programs, to satisfy environmental and safety regulations, and to take advantage of new technology and associated new standards.

Argonne recognizes the contributions that an appropriate setting can make to a world-class laboratory. Natural-habitat areas of Argonne-East are maintained as buffers and for future expansion. Development in all areas of the Argonne-East site is subject to standards for building intensity, coverage, and open space.

At Argonne-West, closure of the Experimental Breeder Reactor-II is scheduled for completion in 2002. This work will place the facility in a safe, stable condition requiring minimal surveillance and maintenance for an indefinite period prior to eventual D&D. Nevertheless, this contaminated facility should be considered a candidate for transfer to DOE-Environmental Management for cleanup.

The demand for hot cell and laboratory facility space at Argonne-West is particularly high. A major focus is providing the facilities and infrastructure needed to deal with spent fuel and nuclear waste (for the electrometallurgical fuel treatment program, for example).

Argonne-West is planning for construction of a major hot cell facility that is needed to handle remotely handled mixed transuranic waste from Argonne-West and INEEL and process the waste for disposal. Disposal of this waste outside Idaho by the year 2018 is required by the court-ordered settlement agreement between DOE and the state of Idaho. Moreover, beyond 2018 this facility will be a cornerstone — along with the Hot Fuel Examination Facility and the Fuel Conditioning Facility — for a much needed DOE hot cell center for developing base technologies to address problems associated with remotely handled waste disposal and to improve nuclear fuels and materials.

D. Security, Export Control, and Counterintelligence

Situation

Both Argonne sites house valuable facilities, equipment, and information that must be protected from theft, disruption, or misuse. Argonne-West also houses significant amounts of special nuclear material (only limited amounts of which are housed at Argonne-East). Increasingly, protection against electronic intrusion is one of the most challenging aspects of security facing the Laboratory.

Argonne's work predominantly involves fundamental research or technology development where the general nature of results is openly disseminated and shared with the scientific community or made available to private industry. The quality of such work depends intrinsically on open dialogue and exchange of information, and that work is exempt from export regulation and is constrained only by prudent management to assure accuracy and appropriate attribution. Nevertheless, certain Laboratory undertakings are subject to export control, security classification, proprietary interest, or other restrictions to which the Laboratory strictly adheres.

Argonne is a leading laboratory in a variety of scientific fields, and it operates major user facilities that are open to researchers from many countries. To serve these missions, the Laboratory each year hosts thousands of foreign visitors and assignees, with whom it encourages active information exchange. The Laboratory also participates in several officially sanctioned programs to aid the transition of workers out of the defense programs of countries of the former

Soviet Union, and it conducts training programs for the International Atomic Energy Agency. As a key player in leading-edge cooperative research and development agreements (CRADAs) with private U.S. industries, Argonne often conducts work involving vital commercial interests.

In order to protect classified, proprietary, or otherwise sensitive information while maintaining broad intellectual openness elsewhere, Argonne maintains processes to define, delineate, and control the information requiring protection. The Argonne-East *Comprehensive Local Threat Statement* notes that protection of classified and sensitive unclassified information is the only "non-low" threat at the Illinois site. Insiders could divert classified or sensitive information, or they could destroy or divert information that has potential economic value to sponsors or to the U.S. economy. The Laboratory also must protect against theft or inadvertent release of sensitive information. Much of this material is maintained on computer files, for which electronic access control (cyber security) is highly challenging, especially given the rapid technological advances available to potential intruders.

Goals

Argonne is fully committed to strict adherence to all federal laws and regulations relating to security, counterintelligence, export control, and nonproliferation, through means consistent with the needs of the Laboratory research community. Important security goals include the following:

- Through site access controls, assure a safe and comfortable working environment for guests of employees and for the large and varied community of researchers using Laboratory facilities.
- Through an active cyber security program, make electronic information freely and readily accessible to authorized users while it is protected against disruption or misuse.
- Through appropriate processes and monitoring, assure controlled access to sensitive and proprietary information by both foreign nationals and U.S. citizens.
- Through an active awareness and information program, make all employees fully appreciate that they are integral to maintaining and enhancing Laboratory security.

Strategies

Protection of physical assets at Argonne requires a combination of access control and surveillance. Protecting hardware and materials at Argonne-East generally involves practices characteristic of industrial security. The site's professional guard force operates under a direct contract with DOE-Chicago Operations. Consideration is being given to transferring to the Laboratory responsibility for managing the guard force, in order to facilitate coordination with other Laboratory functions. The larger quantities of special nuclear material at Argonne-West necessitate more extensive access controls and security force capabilities. The site's security force is armed and certified by DOE to the SPO-II level; some officers are certified to the SPO-III level and can be assigned to special response teams.

Protection of intellectual property involves a complex network of policies, procedures, and practices. Argonne is committed to strict adherence to all federal regulations relating to national security and export control, including all applicable DOE regulations. The keys to the Laboratory's program are access control and awareness training for those who have access to classified or sensitive information. Access control and awareness training are supplemented by an effective cyber security program for both classified and unclassified computing, as well as by appropriate counterintelligence activities. The type and intensity of protective measures match the sensitivity of the information being protected.

For classified data and information, Argonne employs normal DOE security practices, including both personnel and cyber security practices. The Laboratory maintains an active classification program at both its Illinois and Idaho sites. At Argonne-East, the amount of classified information is sufficiently small that total isolation of classified computing from unclassified computing is feasible. At both sites, modern cyber security techniques, including system scans, are used to minimize the potential for loss, disruption, or compromise of electronic information files.

Argonne protects sensitive unclassified information from unauthorized access or disruption by means of a formally documented cyber security program. In addition to general public-use information, this program identifies sensitive information having national security interest; information that is sensitive from the perspective of Laboratory management, operations, and business activities; commercial or proprietary information; and research information that has not yet been approved for release. Network configurations (i.e., hubs and servers) are used to simplify protection against penetration and the detection of attempted penetrations; use of automatic backup features minimizes the potential for data loss. Access to all information other than general public-use information is protected by password and is systematically monitored. Encryption is used where appropriate. DOE reporting and tracking resources are employed to anticipate problems before they occur locally, and a full response capability is maintained. Cyber security systems are regularly evaluated and tested, and improvements are continuously deployed to stay current with changing potential threats. The Laboratory provides computer security training to all computer users.

Argonne maintains a "List of Sensitive Technologies" that identifies unclassified sensitive programs, information, and technologies. Programs, information, and technologies can appear on this list for reasons associated with export control, designation as controlled information (under UCNI ["Unclassified Controlled Nuclear Information"], OUO ["Official Use Only"], or other criteria), or considerations related to privacy or protection of proprietary material. The list is used, along with other sources, to evaluate the export of both hardware and intellectual property, as well as in the review processes for foreign visits and assignments and for foreign travel. Special attention is given to visits and assignments to Argonne of persons from sensitive countries, as well as to travel by Argonne personnel to sensitive countries. Laboratory hosts of all foreign visitors and assignees are given responsibility to protect sensitive information and technologies according to applicable security plans and are explicitly briefed on that responsibility.

At both sites, Argonne maintains an Operations Security (OPSEC) Program designed to provide an acceptable level of assurance that classified and sensitive unclassified information is protected from exploitation by an adversary. The OPSEC Program is the responsibility of the Laboratory's Security organization. An OPSEC Working Group representing both programmatic and operations organizations provides support and oversight to the OPSEC Program. That support includes (1) development and review of the site's OPSEC Program Plan and Comprehensive Local Threat Statement, (2) participation of Working Group members in OPSEC assessments, and (3) review of the status of assessment results and countermeasures. The OPSEC Working Group also will provide oversight and advice to senior management on the Laboratory's broader Safeguards and Security Program, as well as advice to the managers of programs to which the OPSEC Program applies.

Argonne maintains an active counterintelligence program that responds to DOE's *Counterintelligence Implementation Plan.* The Argonne-East office is staffed with a full-time counterintelligence officer, the Argonne-West office with a part-time officer. Full-time clerical staff are being added at both sites to assist in data entry and analysis.

E. Information Management

Situation

Information management at Argonne emphasizes the effective development, communication, and management of scientific, technical, operational, and administrative information. Because of the importance of information management and its associated infrastructure, the two are managed both as integral parts of research programs and as institutional resources.

Within Argonne's research programs, scientific and technical information is acquired, created, and communicated in a fashion customized to programmatic objectives. Through this decentralized approach, life-cycle management of programmatic information is tightly interwoven with the underlying research in order to meet sponsors' expectations. Laboratory programs are also major users of scientific and technical information generated elsewhere, as well as users of internal administrative and operational data. Effective management of business information is also crucial for support organizations.

Argonne provides a wide range of central services to support the digital and traditional collection, creation, dissemination, and archiving of R&D and operations information. Service organizations also operate a Laboratory-wide electronic information infrastructure via a spectrum of systems and services for software development and application, telecommunications, and computing. Strategic planning, funding, and coordinated management for the Laboratory's information infrastructure and systems are addressed collaboratively by policy and planning bodies that are supported by review and implementation teams.

To ensure that the infrastructure evolves as required to support programmatic needs, Argonne leads or collaborates in various national initiatives in information access, networking, and telecommunications, particularly through pilot projects that test the applicability of new information technologies to DOE-funded R&D. The Laboratory maintains national network connections, such as ESnet (the DOE-Science network) and MREN (a high-speed test network in the Chicago metropolitan area). These external networks interface with local Argonne networks and help to position the Laboratory as a major player in national networking initiatives.

Vision

Argonne will maintain high-performance, cost-effective infrastructure and services in computing and information management. These capabilities will support excellence and efficiency in the Laboratory's R&D programs and operations by providing for efficient use of text, data, video, sound, and graphics in all media. At the two major Argonne sites, information infrastructure and services will be provided by support organizations dedicated to helping all Laboratory organizations find, use, and communicate information effectively. Employees will be proficient in the computer-related skills needed to realize the potential of the Laboratory's information systems.

Goals

The primary goal of Argonne's information management efforts is to maximize the ease and effectiveness with which information is acquired, created, modified, stored, retrieved, and applied, both within the Laboratory and with the Laboratory's partners in government, academia, and the private sector. Supporting strategic goals call for Laboratory operations organizations to

- Maintain an efficient, standards-based infrastructure for communications, computer networking, and information systems;
- Continually enhance services that facilitate internal and external information exchange;
- Conduct education programs that upgrade the computer literacy and skills of Laboratory employees;
- Maintain strong core competencies in the emerging and current information technologies that enable timely deployment of systems and services tailored to mission needs; and
- Evaluate emerging information technologies through aggressive use of demonstrations and pilot projects.

Strategies

Argonne's near-term strategies for information management focus on the Laboratory's needs for (1) secure, high-performance telecommunications and networking infrastructure and (2) high-quality Laboratory-wide information systems and services.

For telephone services beyond FY 2000, Argonne plans to take full advantage of competitive market forces to provide cost-effective voice, data, and video network services that can be reconfigured quickly if any single carrier fails. Carriers will be encouraged to provide all these services via dedicated fiber-optic cable. To ensure compatibility and maximum flexibility in meeting future needs, Laboratory strategies call for deploying an internal telecommunications architecture based on standards widely supported by the commercial telephone service providers for their high-speed interconnections. Included in these plans is the eventual replacement of the Laboratory's central telephone switch by merging its functions with the advanced network switching technologies being deployed to address overall telecommunications needs in an integrated way, a trend already apparent in commercial communications.

Networking facilities at Argonne-East include various high-speed network architectures operating on a fiber-optic cable plant. The current cable plant will allow deployment of standard technologies to support bandwidths into the multigigabit-per-second range. Remote-access systems are being reengineered to allow secure use of Internet service providers, and Laboratory networks are being upgraded to provide redundancy and security. Test beds based on appropriate standards, already in place at the Laboratory, ensure Argonne's interoperability with other DOE sites and commercial service providers. In support of DOE's Information Architecture Initiative, Argonne actively participates in DOE standards committees and task groups.

Argonne is working with the National Energy Research Supercomputer Center and several other national laboratories and agencies to develop cross-realm authentications for the ESnet wide-area network and the emerging next-generation Internet. Argonne is also participating in a DOE pilot project to demonstrate high-performance network environments linked across dedicated commercial interconnections, in preparation for the advanced fast-packet-switching services that will soon be offered generally via ESnet. These advanced networking initiatives are particularly important as infrastructure for high-performance computing programs at the Laboratory and for providing convenient access to user facilities such as the APS.

The Laboratory operates a suite of central information systems to manage R&D information and business data in the areas of libraries, publications and records tracking, finance, human resources, procurement, facilities, environmental protection, and employee health and safety. These systems are developed under Argonne's *Administrative Computing Strategic Plan*, which is prepared by an oversight committee comprising senior management representatives from programmatic and operations organizations. These Laboratory-wide information systems operate in an integrated client-server environment on UNIX and NT servers and desktop computers. The Laboratory's continuing strategy is to use commercially available applications software to the greatest extent possible in administrative and operational systems. The Laboratory will continue to streamline and automate business processes to take full advantage of the capabilities of current information system software. New initiatives will improve Laboratory-wide access to data supporting both R&D and operations functions and will more fully implement electronic commerce in the Laboratory's business activities.

A key near-term strategy for simplifying user access to operational and administrative information is expanded use of World Wide Web interfaces to the Laboratory's information systems. Argonne's ongoing development of electronic document capabilities is emphasizing conversion of Laboratory manuals to Web-compatible digital forms, enhancement of browsing and search tools for scientific and technical information, and acquisition of electronic publications constituting a "virtual library."

Finally, because Argonne's R&D programs are increasingly publishing their results primarily in digital form, the Laboratory's support organizations will continue to exploit the most effective electronic media available for dissemination of scientific and technical information. In support of this goal, Argonne participates actively in an ongoing DOE-wide collaboration that aims (1) to increase the visibility of national laboratory R&D publications via enhanced on-line access and (2) to maximize sharing of digital library resources among laboratories.

F. Communications, Outreach, and Community Affairs

Situation

To conduct its R&D operations efficiently and effectively, Argonne must have the confidence and support of its stakeholders. The Laboratory's major non-DOE stakeholders include Argonne employees, the research community, local and national news media, the trade press, the broad national public, and members of the public living near the two Argonne sites. Accordingly, the Laboratory takes special care to maintain close, positive relationships with all these groups and to foster a climate of mutual trust. This effort involves constant attention to two-way communications that are accurate, clear, timely, and credible. An active and growing outreach program seeks to inform Argonne's constituents about the Laboratory's work and to involve them constructively in its activities.

The major elements of Argonne's programs in Communications, Outreach, and Community Affairs involve the following activities:

- *Employee Communications.* Argonne's weekly employee newsletter, according to a recent survey, is read in its entirety or in part by more than 99% of employees. Employee communications are also well served by sitewide electronic mail broadcasts, a continually updated intranet, a telephone INFO-line, on-site technical and scientific seminars and conferences, colloquia featuring renowned speakers, and a variety of special employee events. An annual highlight is the "State of the Laboratory" address by Argonne's director.

- *The Research Community.* Ongoing communications with peers in the research community are conducted by staff who publish in total more than 2,000 research papers and reports annually and who participate in scientific and technical conferences — often presenting papers or sponsoring events.

- *Media Relations.* Argonne's external communications efforts mainly target the news media, which constitute the Laboratory's major avenue for informing the national and local public about both the long-term value of scientific research in general and the benefits of Argonne and DOE-funded research in particular.

- *Trade Press.* The trade press is an important vehicle for informing industrial researchers and executives about Argonne's research and facilities, which can help industry solve its research problems and can lead to other productive relationships, such as R&D partnerships.

- *Community Affairs.* Argonne's wide-ranging community affairs programs reach all of the Laboratory's major stakeholder groups. These programs include site tours, open houses and other special events, speeches by staff to external audiences, and a vast array of Laboratory-sponsored conferences and seminars.

Goals and Strategies

Argonne continually seeks opportunities to further strengthen the Laboratory's programs in Communications, Outreach, and Community Affairs. Pursuit of the following important opportunities is under way or being planned:

- To enhance Argonne's ability to inform the national public about the value of research conducted by Argonne and the DOE national laboratory system, the Laboratory has worked with DOE's Chicago Operations Office to employ a national public relations agency. The program's first year, which is currently under way, will be used to evaluate its success and determine whether it should be continued.

- The Laboratory is increasing its traditional outreach to the general science news media through efforts such as increased representation at press briefings and annual meetings of professional research societies.

- The science content of Argonne's quarterly magazine *logos* is being increased, and the publication is being repositioned to target a primary audience of researchers and "the interested layperson."

- Laboratory senior researchers and communicators will consider the possibility of creating a family of inexpensive, one-page, small-circulation newsletters targeted specifically to trade magazines, industrial R&D executives, and researchers in specific fields.

- The Laboratory's services supporting community affairs, special events, and conferences have been streamlined and integrated more tightly, and new programs are being implemented to provide expanded support for off-site meetings and conferences organized on short notice.

- To better serve the informational needs of business and civic groups near the Argonne-East site, a plan will be developed to integrate and coordinate requests from the public for speakers from Argonne and DOE-Chicago Operations.

- Argonne will continue to work closely with DOE-Chicago Operations and its Argonne Group to nurture a series of monthly meetings with leaders from communities neighboring Argonne-East. This highly successful Community Leaders Roundtable keeps Argonne's neighbors informed about the Laboratory's activities and expected impacts on the surrounding area and provides an informal forum for feedback.

For more than 50 years, Argonne has benefited from remarkably strong community support, positive news media relations, and strong management commitment to communications and outreach. The strategies outlined above are designed to build on those successes.

G. Performance-Based Management

Situation

The performance-based *Prime Contract* under which the University of Chicago operates Argonne for the Department of Energy provides objectives, measures, and incentives for the Laboratory that foster outstanding performance. During the current contract's first 14 months, ending in September 1996, Argonne developed a formal system for tracking and reporting performance data that satisfied Appendix B of the contract and was well received by DOE. An extension to the initial five-year term of this contract became effective on October 1, 1999.

The Laboratory's measured performance — both in science and technology and in operations areas designated as critical — determines the performance fee that the University receives and also a performance payment pool for employees. The performance-based contract for operation of Argonne is a coordinated part of DOE's comprehensive Strategic Management System, which uses consideration of performance as the common link that meshes interrelated budgeting and program evaluation processes. Argonne sees strong evidence that performance evaluation facilitates continuous improvement in its operations much more effectively than would compliance-based approaches.

Goals

Management of Argonne under the performance-based *Prime Contract* has the following central goals:

- Maximize the productivity of the Laboratory's research programs.

- Maximize performance in key areas of Laboratory operations management, including leadership, ES&H, business and contract management, financial management, subcontract management, intellectual property and technology transfer, and human resources management.

- Maintain and enhance the capabilities and core competencies that will maximize the Laboratory's future performance.

Strategies

In addition to defining DOE performance and compliance requirements, the *Prime Contract* for operation of Argonne also establishes measurement mechanisms in both programmatic and operations areas. The *Prime Contract* extension maintains this type of measurement and reporting structure. ES&H performance is formally measured in the operations section of Appendix B of the *Prime Contract*, but ES&H performance is understood to be integral to measured performance in both programmatic and operations areas. Strict attention to a safe and environmentally sound workplace is the first attribute of the high-quality science and technology produced by the Laboratory.

Science and Technology Programs. Argonne's science and technology programs have received an overall performance rating of "outstanding," the highest possible, in each year of the current performance-based *Prime Contract*. These ratings are developed by DOE's Argonne Group on the basis of (1) appraisals of the Laboratory's work by the several DOE program offices that are major sponsors and (2) peer reviews of Laboratory programs organized by the University's Board of Governors for Argonne. Ratings by the individual DOE offices are based on criteria specified in the *Prime Contract*. In a manner appropriate to each program, evaluation criteria fall into the broad areas of quality of research, relevance to DOE missions and national needs, success in constructing and operating research facilities, and effectiveness and efficiency of research program management. Ratings by the individual DOE offices are weighted by funding levels to determine the Laboratory's overall rating.

The formal DOE evaluation process is based on scientific peer review, which is generally understood to be the most broadly reliable basis for guiding and evaluating research. Reviews of Argonne's performance by DOE program offices can take advantage of the peer reviews of Laboratory research programs conducted by visiting committees organized by the Board of Governors for Argonne. For a given Laboratory program, committee visits occur at intervals of 12 to 24 months. Members of the committees are drawn from the external scientific, engineering, and business communities, and committee reviews serve directly as valuable guides for individual research programs and for senior Laboratory management.

Operations. Operations activities at Argonne encompass leadership, administrative, business, and technical support for science and technology programs; management and operation of the physical plant, along with construction of new facilities; and management of ES&H programs. The *Prime Contract* distinguishes specific functional performance areas within operations, ranging from Diversity to Technology Transfer and to Financial Management. Distinct objectives, measures, and performance expectations are specified for each area. Over the life of the current contract, Argonne has received ratings for the major reporting areas that fall, with few exceptions, in the range of "excellent" to "outstanding." These ratings are based on (1) scores on measurements defined by the *Prime Contract*, (2) DOE's evaluation of the Laboratory's annual self-assessment in the various operations performance areas, and (3) consideration of significant activities or incidents that occurred at the Laboratory.

Self-Assessment. In keeping with the spirit and intent of the *Prime Contract*, Argonne has developed a multifaceted reporting and self-assessment process. To assess its operational performance, the Laboratory uses results from *Prime Contract* measurements, but it also looks beyond these measures to consider activities that contribute significantly to overall Laboratory performance. Each administrative, business, and operations organizational unit within the Laboratory's support organizations reports monthly or quarterly and completes its own self-assessment focusing on performance areas specified as relevant in Appendix B of the *Prime Contract*. Results from these organizational reports and self-assessments are integrated and reported by functional area in an annual self-assessment document. Monthly reports and the annual document are made available via the Internet, enhancing communications between DOE and the Laboratory.

In the coming year, Argonne staff responsible for administering the performance-based *Prime Contract* will continue to

- Communicate responsibilities under the contract to Laboratory organizations in order to encourage improved performance and better understanding of its achievement;
- Facilitate improved measurement of performance under the contract; and
- Enhance communication regarding performance issues among the Laboratory, the University, and DOE.

H. Productivity Improvement and Overhead Cost Reduction

Situation

For more than a decade, Argonne has maintained a disciplined, methodical system for reviewing and controlling overhead costs. The Laboratory's overhead management process has contributed significantly to achievement of a reduced overhead rate over the past several years, a time when DOE initiatives exerted great cost pressure. This systematic, detailed, bottom-up process involves scientific and operations managers in establishing a budget for each nondirect functional area. Through this process, the Laboratory has been able to reduce its overhead cost percentage from 22.4% in FY 1994 to 19.3% in FY 1999, yet maintain an efficient balance between scientific and support personnel. The overhead cost percentage is projected to remain constant in FY 2000. In terms of DOE's three high-level productivity metrics, Table V.1 summarizes Argonne's history and current status.

Table V.1 Productivity Metrics

	Actual Values						Objectives
	FY94	FY95	FY96	FY97	FY98	FY99	FY00
Research-to-Support (Labor Dollar) Ratio[a]	2.10	2.20	2.20	2.20	2.30	2.30	2.30
Technical Labor on Research (%)[b]	86.0	84.6	85.0	86.0	87.0	85.0	85.0
Multiplier Composite	-	-	-	-	1.64	1.64	-
Average Operating Cost per Research FTE[c]	137.5	134.1	131.8	130.3	130.4	132.1	131.0

[a]Research labor dollars divided by support labor dollars.
[b]Technical labor dollars divided by research labor dollars, multiplied by 100.
[c]Thousands of FY 1994 dollars per year per FTE.

Goal

Argonne's overall goal is to achieve productivity improvement sufficient to accommodate a moderate decline in the Laboratory's constant-dollar total resources through increased efficiency and effectiveness in its overhead and technical support services, while maintaining a stable scientific workforce.

Strategies

Under its current *Prime Contract*, Argonne is responsible for developing and implementing its own personnel policies and procedures. An appendix to the contract gives the Laboratory the flexibility needed to control its cost growth through containment of staffing levels, pay, and benefits and at the same time to improve its performance.

Table V.1 gives Argonne's FY 2000 objectives for DOE's three high-level financial management performance metrics, as they were originally established in FY 1996. As in FY 1997-FY 1999, the Laboratory projects that it will meet its objectives for FY 2000 through continuing improvements in the productivity of its support activities. The Laboratory's cost per research FTE (full-time equivalent) increased slightly in FY 1999 because of a substantial number of staff terminations in one program area. However, Argonne's cost per research FTE remains among the lowest for a DOE multiprogram laboratory.

In August 1999, a meeting to review productivity metrics at the national laboratories was held at the request of the DOE under secretary. The attendees decided that consistent ways of assessing research performance across the various laboratories should be developed as a complement to the financial performance metrics shown in Table V.1. The metrics in Table V.1 will continue to be reported through FY 2000, after which time the research-to-support ratio will continue to be used, the technical labor percent metric will be dropped, and the cost per research FTE will be replaced by a set of multiplier metrics.

The multiplier performance metrics were initially proposed in FY 1998, and a pilot program was established to confirm their usefulness. These metrics essentially measure the extent to which overhead costs add to various sets of defined direct costs at a laboratory. A composite multiplier for the entire laboratory is also calculated. Argonne decided to implement these multiplier performance metrics as part of its internal financial management beginning in FY 1998. The resulting composite multipliers shown in Table V.1 are, according to preliminary indications, among the lowest for a DOE multiprogram laboratory.

Argonne has been very successful in reducing its overhead costs to meet increasingly ambitious goals. However, past success in restructuring and streamlining overhead activities makes further improvements increasingly difficult to achieve without adversely affecting services needed by the Laboratory's research programs or jeopardizing compliance with safety and environmental regulations.

VI. Resource Projections

The resource projections in this chapter are considered a reasonable baseline for planning the desired future of the Laboratory and for addressing important contingencies, particularly those associated with increasingly stringent federal budgets. The projections do not necessarily represent the outcome that the Laboratory considers most likely.

The projections show levels of activity at Laboratory, program, and subprogram levels. The resources required for Argonne's initiatives for years beyond FY 2000 generally are not included in these resource projections. Funds received in FY 1999 and FY 2000 for initiatives are included in the funding levels shown for those years. Only funded and budgeted construction projects are included in the tables, except in Tables VI.1 and VI.3, which also specify funding for proposed construction projects.

The figures for FY 1999 represent historical dollar values. The FY 2000 figures are midyear projections in current dollars. Projections beyond FY 2000 incorporate annual cost escalation percentages that have been reviewed by DOE.

The resource projections are presented in 20 tables:

- Tables VI.1 and VI.2 summarize Laboratory total funding and full-time-equivalent (FTE) personnel levels, respectively.
- Table VI.3 summarizes the information in Tables VI.4-VI.20, giving total Laboratory funding for each DOE secretarial office.
- Tables VI.4-VI.20 give operating, capital equipment, and construction funding along with FTE personnel levels for each subprogram within specified DOE secretarial offices and for work supported by non-DOE organizations. Tables VI.4-VI.17 describe work funded directly by DOE, Table VI.18 considers work funded by DOE contractors (as well as funds transferred by Argonne to other DOE contractors), and Tables VI.19 and VI.20 pertain to work funded by all other organizations.

Table VI.1 Laboratory Funding Summary ($ in millions BA)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
DOE Funding	393.8	404.8	459.9	501.9	484.0	474.7	474.7	474.7
Funds Transferred to Other DOE Contractors	-9.0	-11.0	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
Work for Others (WFO) Program	66.7	71.8	70.9	75.2	69.4	69.1	69.1	69.1
Additional Work for Non-DOE Organizations	7.7	6.0	7.0	7.9	7.3	7.3	7.0	7.5
Total Operating	459.2	471.6	528.8	576.0	551.7	542.1	541.8	542.3
Capital Equipment[a]	18.8	14.9	17.5	22.7	22.9	23.1	23.1	23.1
Construction[a]	4.8	6.5	4.5	0.0	0.0	0.0	0.0	0.0
Inventory	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Equipment	1.6	1.6	2.2	2.5	2.8	3.2	3.5	4.0
General Plant Projects	5.6	5.3	14.1	9.9	11.0	10.5	10.7	11.0
Multiprogram Energy Laboratories — Facilities Support Program	7.1	5.0	6.6	2.0	0.0	0.0	0.0	0.0
Total Laboratory Funding	497.1	504.9	573.7	613.1	588.4	578.9	579.1	580.4
Proposed Projects:								
Program Construction	0.0	0.0	0.0	9.0	19.0	29.0	34.0	24.0
Multiprogram Energy Laboratories — Facilities Support Program	0.0	0.0	0.0	2.2	87.0	43.4	37.1	8.2
Total Projected Funding	497.1	504.9	573.7	624.3	694.4	651.3	650.2	612.6

[a]Capital equipment and construction can include funding from sources other than DOE.

Table VI.2 Laboratory Personnel Summary (in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Direct Personnel								
DOE Effort	1848.7	1839.2	2009.6	2040.8	2001.7	1941.9	1940.1	1927.3
Work for Others (WFO) Program	260.0	237.6	226.8	224.5	221.8	218.8	218.8	218.8
Additional Work for Non-DOE Organizations[a]	17.4	23.0	26.0	28.0	32.0	32.0	30.0	33.0
Total Operating	2126.1	2119.3	2262.4	2293.3	2255.5	2192.7	2188.9	2179.1
Other Direct[b]	561.0	574.1	446.9	453.3	450.9	440.6	442.1	435.2
Total Direct Personnel	2687.1	2693.4	2709.3	2746.6	2706.4	2633.3	2631.0	2614.3
Indirect Personnel	1319.1	1256.7	1296.9	1314.8	1295.6	1260.6	1259.5	1251.5
Total Personnel	4006.2	3950.1	4006.2	4061.4	4002.0	3893.9	3890.5	3865.8

[a]Includes FTEs associated with services provided to APS users and work for CRADA partners.

[b]"Other direct" personnel includes FTEs for general Laboratory services, program management and administration, staff temporary assignments, and a portion of work for other DOE contractors that is funded through reconciling transfers.

Table VI.3 Funding by Assistant Secretarial Office ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
DOE WORK								
Table VI.4 — Science								
Operating	178.2	178.3	211.5	250.8	252.4	253.4	253.4	253.4
Capital Equipment	15.8	12.4	14.8	20.4	20.7	20.9	20.9	20.9
General Purpose Equipment	1.6	1.6	2.2	2.5	2.8	3.2	3.5	4.0
Construction	4.8	3.5	4.5	0.0	0.0	0.0	0.0	0.0
General Plant Projects	5.6	5.3	13.1	7.9	9.0	9.0	9.2	9.5
Subtotal	206.0	201.1	246.1	281.6	284.9	286.5	287.0	287.8
Inventory	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Multiprogram Energy Laboratories — Facilities Support Program	7.1	5.0	6.6	2.0	0.0	0.0	0.0	0.0
Total Science	213.1	206.1	252.7	283.6	284.9	286.5	287.0	287.8
Direct Personnel	886.5	946.5	1044.9	1131.1	1133.3	1133.3	1133.3	1133.3
Table VI.5 — Nuclear Energy, Science and Technology								
Operating	82.7	79.9	83.8	83.4	83.7	83.9	83.9	83.9
Capital Equipment	0.0	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	0.0
General Plant Projects	0.0	0.0	0.0	0.0	1.0	1.5	1.5	1.5
Total	82.7	79.9	83.8	83.4	84.7	85.4	85.4	85.4
Direct Personnel	429.1	383.9	384.4	366.3	351.8	336.0	336.0	336.0
Table VI.6 — Energy Efficiency and Renewable Energy								
Operating	33.2	35.8	43.1	42.1	42.1	42.1	42.1	42.1
Capital Equipment	2.2	2.0	2.3	2.0	2.0	2.0	2.0	2.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	35.4	37.8	45.4	44.1	44.1	44.1	44.1	44.1
Direct Personnel	134.0	164.5	173.6	169.8	169.8	169.8	169.8	169.8
Table VI.7 — Fossil Energy								
Operating	4.1	4.2	5.1	4.8	4.8	4.8	4.8	4.8
Capital Equipment	0.0	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	0.0
Total	4.1	4.2	5.1	4.8	4.8	4.8	4.8	4.8
Direct Personnel	18.3	24.4	25.4	21.4	21.4	21.4	21.4	21.4

Table VI.3 Funding by Assistant Secretarial Office (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Table VI.8 — Environmental Management								
Operating	30.2	28.9	18.6	21.3	15.3	8.7	8.7	8.7
Capital Equipment	0.1	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	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	30.3	28.9	18.6	21.3	15.3	8.7	8.7	8.7
Direct Personnel	125.4	116.5	71.1	65.5	65.5	39.0	39.0	39.0
Table VI.9 — Defense Programs								
Operating	5.5	2.6	1.7	1.6	1.5	1.5	1.5	1.5
Capital Equipment	0.4	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	0.0
Total	5.9	2.6	1.7	1.6	1.5	1.5	1.5	1.5
Direct Personnel	20.2	13.0	3.8	3.2	3.1	3.1	3.1	3.1
Table VI.10 — Defense Nuclear Nonproliferation								
	19.9	20.6	40.3	42.3	28.5	24.6	24.6	24.6
Operating	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	20.2	20.9	40.6	42.6	28.7	24.8	24.8	24.8
Total	72.0	83.9	109.5	105.9	88.8	78.6	78.3	78.3
Direct Personnel								
Table VI.11 — Environment, Safety, and Health								
Operating	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	0.0	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	0.0
Total	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	2.3	3.3	3.0	2.9	2.9	2.9	2.9	2.9
Table VI.12 — Policy								
Operating	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.7	1.4	1.1	1.1	1.1	1.1	1.1	1.1

Table VI.3 Funding by Assistant Secretarial Office (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Table VI.13 — Economic Impact and Diversity								
Operating	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.9	0.7	0.6	0.6	0.6	0.6	0.6	0.6
Table VI.14 — Counterintelligence								
Operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Table VI.15 — Federal Energy Regulatory Commission								
Operating	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	0.0	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	0.0
Total	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	0.0	0.5	0.6	0.6	0.6	0.6	0.6	0.6
Table VI.16 — Intelligence								
Operating	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	0.0	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	0.0
Total	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	1.8	1.8	2.2	2.2	2.1	2.0	2.0	2.0
Table VI.17 — Security and Emergency Operations								
Operating	0.7	13.1	15.3	15.1	15.2	15.2	15.2	15.2
Capital Equipment	0.0	0.2	0.1	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	0.0
General Plant Projects	0.0	0.0	1.0	2.0	1.0	0.0	0.0	0.0
Total	0.7	13.3	16.4	17.1	16.2	15.2	15.2	15.2
Direct Personnel	2.7	9.1	96.1	94.8	94.8	94.5	94.5	94.5

Table VI.3 Funding by Assistant Secretarial Office (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Table VI.18 — Work for Other DOE Contractors								
Operating	37.8	40.0	39.0	39.0	39.0	39.0	39.0	39.0
Capital Equipment	0.0	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	0.0
Total	37.8	40.0	39.0	39.0	39.0	39.0	39.0	39.0
Direct Personnel	154.7	109.2	93.3	75.4	65.9	59.0	57.5	44.7
TOTAL WORK FOR DOE PROGRAMS								
Operating	393.8	404.8	459.9	501.9	484.0	474.7	474.7	474.7
Capital Equipment	18.8	14.9	17.5	22.7	22.9	23.1	23.1	23.1
General Purpose Equipment	1.6	1.6	2.2	2.5	2.8	3.2	3.5	4.0
Construction	4.8	3.5	4.5	0.0	0.0	0.0	0.0	0.0
General Plant Projects	5.6	5.3	14.1	9.9	11.0	10.5	10.7	11.0
Subtotal	424.6	430.1	498.2	537.0	520.7	511.5	512.0	512.8
Inventory	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Multiprogram Energy Laboratories — Facilities Support Program	7.1	5.0	6.6	2.0	0.0	0.0	0.0	0.0
Total	431.7	435.1	504.8	539.0	520.7	511.5	512.0	512.8
Funds Transferred to Other DOE Contractors (Operating)	-9.0	-11.0	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
Table VI.19 — Work for Others (WFO) Program								
Operating	66.7	71.8	70.9	75.2	69.4	69.1	69.1	69.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	66.7	74.8	70.9	75.2	69.4	69.1	69.1	69.1
Direct Personnel	260.0	237.6	226.8	224.5	221.8	218.8	218.8	218.8
Table VI.20 — Additional Work for Non-DOE Organizations								
Operating	7.7	6.0	7.0	7.9	7.3	7.3	7.0	7.5
Capital Equipment	0.0	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	0.0
Total	7.7	6.0	7.0	7.9	7.3	7.3	7.0	7.5
Direct Personnel	17.4	23.0	26.0	28.0	32.0	32.0	30.0	33.0
TOTAL OPERATING FUNDING	459.2	471.6	528.8	576.0	551.7	542.1	541.8	542.3
TOTAL CAPITAL EQUIPMENT	18.8	14.9	17.5	22.7	22.9	23.1	23.1	23.1

Table VI.3 Funding by Assistant Secretarial Office (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
TOTAL CONSTRUCTION	4.8	6.5	4.5	0.0	0.0	0.0	0.0	0.0
TOTAL INVENTORY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL GENERAL PURPOSE EQUIPMENT	1.6	1.6	2.2	2.5	2.8	3.2	3.5	4.0
TOTAL GENERAL PLANT PROJECTS	5.6	5.3	14.1	9.9	11.0	10.5	10.7	11.0
TOTAL MULTIPROGRAM ENERGY LABORATORIES — FACILITIES SUPPORT PROGRAM	7.1	5.0	6.6	2.0	0.0	0.0	0.0	0.0
GRAND TOTAL LABORATORY FUNDING	497.1	504.9	573.7	613.1	588.4	578.9	579.1	580.4
TOTAL PROPOSED PROJECTS								
TOTAL PROGRAM CONSTRUCTION	0.0	0.0	0.0	9.0	19.0	29.0	34.0	24.0
TOTAL MULTIPROGRAM ENERGY LABORATORIES — FACILITIES SUPPORT PROGRAM	0.0	0.0	0.0	2.2	87.0	43.4	37.1	8.2
GRAND TOTAL PROJECTED FUNDING	497.1	504.9	573.7	624.3	694.4	651.3	650.2	612.6

Table VI.4 Science: Resources by Subprogram ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Fusion Energy Sciences (AT)								
Operating	2.6	2.3	2.7	2.9	3.2	3.2	3.2	3.2
Capital Equipment	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.6	2.3	2.7	2.9	3.3	3.3	3.3	3.3
Direct Personnel	11.8	12.2	12.9	13.7	13.8	13.8	13.8	13.8
Research and Technology (KA-04)								
Operating	7.9	8.1	9.0	10.4	10.7	10.7	10.7	10.7
Capital Equipment	0.0	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	0.0
Total	7.9	8.1	9.0	10.4	10.7	10.7	10.7	10.7
Direct Personnel	46.8	53.1	53.6	60.6	60.6	60.6	60.6	60.6
High Energy Physics Facilities (KA-05)								
Operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	1.8	1.8	1.8	1.9	2.0	2.2	2.2	2.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1.8	1.8	1.8	1.9	2.0	2.2	2.2	2.2
Direct Personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total High Energy Physics (KA)								
Operating	7.9	8.1	9.0	10.4	10.7	10.7	10.7	10.7
Capital Equipment	1.8	1.8	1.8	1.9	2.0	2.2	2.2	2.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	9.7	9.9	10.8	12.3	12.7	12.9	12.9	12.9
Direct Personnel	46.8	53.1	53.6	60.6	60.6	60.6	60.6	60.6
Medium Energy Physics (KB-01)								
Operating	3.0	3.2	3.3	3.9	3.9	3.9	3.9	3.9
Capital Equipment	0.2	0.1	0.2	0.3	0.3	0.3	0.3	0.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	3.2	3.3	3.5	4.2	4.2	4.2	4.2	4.2
Direct Personnel	18.2	19.5	19.5	20.1	22.2	22.2	22.2	22.2
Heavy-Ion Physics (KB-02)								
Operating	10.9	10.8	11.0	13.6	13.6	13.6	13.6	13.6
Capital Equipment	1.3	1.3	1.2	1.9	1.9	1.9	1.9	1.9
Construction	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.0
Total	12.6	12.5	12.6	15.5	15.5	15.5	15.5	15.5
Direct Personnel	64.1	65.9	64.9	72.0	72.0	72.0	72.0	72.0

Table VI.4 Science: Resources by Subprogram (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Nuclear Theory (KB-03)								
Operating	0.9	0.9	0.9	1.7	1.7	1.7	1.7	1.7
Capital Equipment	0.0	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	0.0
Total	0.9	0.9	0.9	1.7	1.7	1.7	1.7	1.7
Direct Personnel	6.6	6.5	6.5	9.5	9.5	9.5	9.5	9.5
Low Energy Physics (KB-04)								
Operating	0.3	0.8	0.2	3.8	3.8	3.8	3.8	3.8
Capital Equipment	0.0	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	0.0
Total	0.3	0.8	0.2	3.8	3.8	3.8	3.8	3.8
Direct Personnel	2.0	2.7	0.8	11.0	11.0	11.0	11.0	11.0
Total Nuclear Physics (KB)								
Operating	15.1	15.7	15.4	23.0	23.0	23.0	23.0	23.0
Capital Equipment	1.5	1.4	1.4	2.2	2.2	2.2	2.2	2.2
Construction	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.0
Total	17.0	17.5	17.2	25.2	25.2	25.2	25.2	25.2
Direct Personnel	90.9	94.6	91.7	112.6	114.7	114.7	114.7	114.7
Materials Sciences (KC-02)								
Operating	27.1	30.7	40.8	44.0	44.2	44.3	44.3	44.3
Capital Equipment	2.8	4.3	3.0	5.8	5.8	5.8	5.8	5.8
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	29.9	35.0	43.8	49.8	50.0	50.1	50.1	50.1
Direct Personnel	157.5	157.2	212.3	228.8	228.8	228.8	228.8	228.8
Advanced Photon Source (KC-02)								
Operating	79.0	80.0	85.0	98.2	98.2	98.2	98.2	98.2
Capital Equipment	4.9	2.6	5.6	7.2	7.2	7.2	7.2	7.2
Construction	4.4	3.1	4.1	0.0	0.0	0.0	0.0	0.0
Total	88.3	85.7	94.7	105.4	105.4	105.4	105.4	105.4
Direct Personnel	394.7	449.2	461.6	469.2	469.2	469.2	469.2	469.2
Total Materials Sciences (KC-02)								
Operating	106.1	110.7	125.8	142.2	142.4	142.5	142.5	142.5
Capital Equipment	7.7	6.9	8.6	13.0	13.0	13.0	13.0	13.0
Construction	4.4	3.1	4.1	0.0	0.0	0.0	0.0	0.0
Total	118.2	120.7	138.5	155.2	155.4	155.5	155.5	155.5
Direct Personnel	552.2	606.4	673.9	698.0	698.0	698.0	698.0	698.0

Table VI.4 Science: Resources by Subprogram (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Chemical Sciences (KC-03)								
Operating	15.8	14.9	15.5	16.4	17.2	17.2	17.2	17.2
Capital Equipment	3.9	1.8	1.7	1.8	1.9	1.9	1.9	1.9
General Purpose Equipment	1.6	1.6	2.2	2.5	2.8	3.2	3.5	4.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	5.6	5.3	10.1	7.9	9.0	9.0	9.2	9.5
Total	26.9	23.6	29.5	28.6	30.9	31.3	31.8	32.6
Direct Personnel	74.2	76.6	75.0	77.0	77.0	77.0	77.0	77.0
Engineering and Geosciences (KC-04)								
Operating	0.8	0.5	0.6	0.6	0.6	0.6	0.6	0.6
Capital Equipment	0.6	0.4	0.3	0.4	0.4	0.4	0.4	0.4
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1.4	0.9	0.9	1.0	1.0	1.0	1.0	1.0
Direct Personnel	3.0	3.9	3.3	3.5	3.5	3.5	3.5	3.5
Total Basic Energy Sciences (KC-02, KC-03, KC-04)								
Operating	122.7	126.1	141.9	159.2	160.2	160.3	160.3	160.3
Capital Equipment	12.2	9.1	10.6	15.2	15.3	15.3	15.3	15.3
General Purpose Equipment	1.6	1.6	2.2	2.5	2.8	3.2	3.5	4.0
Construction	4.4	3.1	4.1	0.0	0.0	0.0	0.0	0.0
General Plant Projects	5.6	5.3	10.1	7.9	9.0	9.0	9.2	9.5
Total	146.5	145.2	168.9	184.8	187.3	187.8	188.3	189.1
Direct Personnel	629.4	686.9	752.2	778.5	778.5	778.5	778.5	778.5
Mathematical, Information, and Computational Sciences (KJ-01)								
Operating	16.0	11.6	10.2	22.1	22.1	23.0	23.0	23.0
Capital Equipment	0.4	0.0	0.0	0.6	0.6	0.6	0.6	0.6
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	16.4	11.6	10.2	22.7	22.7	23.6	23.6	23.6
Direct Personnel	43.0	42.0	42.0	73.0	73.0	73.0	73.0	73.0
Laboratory Technology Research (KJ-02)								
Operating	2.3	1.3	1.9	2.4	2.4	2.4	2.4	2.4
Capital Equipment	0.0	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	0.0
Total	2.3	1.3	1.9	2.4	2.4	2.4	2.4	2.4
Direct Personnel	15.4	11.1	9.9	11.4	11.4	11.4	11.4	11.4

Table VI.4 Science: Resources by Subprogram (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Advanced Energy Projects (KJ-03)								
Operating	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Computational and Technology Research (KJ)								
Operating	18.8	12.9	12.1	24.5	24.5	25.4	25.4	25.4
Capital Equipment	0.4	0.0	0.0	0.6	0.6	0.6	0.6	0.6
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	19.2	12.9	12.1	25.1	25.1	26.0	26.0	26.0
Direct Personnel	60.6	53.1	51.9	84.4	84.4	84.4	84.4	84.4
Life Sciences (KP-11)								
Operating	6.2	4.7	8.4	8.8	8.8	8.8	8.8	8.8
Capital Equipment	-0.2	0.1	0.8	0.3	0.3	0.3	0.3	0.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
Total	6.0	4.8	12.2	9.1	9.1	9.1	9.1	9.1
Direct Personnel	29.5	24.9	45.3	44.7	44.7	44.7	44.7	44.7
Environmental Processes (KP-12)								
Operating	3.4	7.0	20.2	20.3	20.3	20.3	20.3	20.3
Capital Equipment	0.1	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	3.5	7.0	20.4	20.5	20.5	20.5	20.5	20.5
Direct Personnel	13.8	17.3	31.0	31.0	31.0	31.0	31.0	31.0
Environmental Remediation (KP-13)								
Operating	0.6	0.8	0.9	0.9	0.9	0.9	0.9	0.9
Capital Equipment	0.0	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	0.0
Total	0.6	0.8	0.9	0.9	0.9	0.9	0.9	0.9
Direct Personnel	2.2	3.0	4.7	4.4	4.4	4.4	4.4	4.4
Medical Applications and Measurement Science (KP-14)								
Operating	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.3	0.4	0.4	0.0	0.0	0.0	0.0	0.0

Table VI.4 Science: Resources by Subprogram (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Total Biological and Environmental Research (KP)								
Operating	10.3	12.6	29.6	30.0	30.0	30.0	30.0	30.0
Capital Equipment	-0.1	0.1	1.0	0.5	0.5	0.5	0.5	0.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
Total	10.2	12.7	33.6	30.5	30.5	30.5	30.5	30.5
Direct Personnel	45.8	45.6	81.4	80.1	80.1	80.1	80.1	80.1
Total Office of Science Program Direction (KX)								
Operating	0.8	0.6	0.8	0.8	0.8	0.8	0.8	0.8
Capital Equipment	0.0	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	0.0
Total	0.8	0.6	0.8	0.8	0.8	0.8	0.8	0.8
Direct Personnel	1.2	1.0	1.2	1.2	1.2	1.2	1.2	1.2
Total Science								
Operating	178.2	178.3	211.5	250.8	252.4	253.4	253.4	253.4
Capital Equipment	15.8	12.4	14.8	20.4	20.7	20.9	20.9	20.9
General Purpose Equipment	1.6	1.6	2.2	2.5	2.8	3.2	3.5	4.0
Construction	4.8	3.5	4.5	0.0	0.0	0.0	0.0	0.0
General Plant Projects	5.6	5.3	13.1	7.9	9.0	9.0	9.2	9.5
Subtotal	206.0	201.1	246.1	281.6	284.9	286.5	287.0	287.8
Direct Personnel	886.5	946.5	1044.9	1131.1	1133.3	1133.3	1133.3	1133.3
Inventory	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Multiprogram Energy Laboratories — Facilities Support Program	7.1	5.0	6.6	2.0	0.0	0.0	0.0	0.0
Total Science	213.1	206.1	252.7	283.6	284.9	286.5	287.0	287.8

Table VI.5 Nuclear Energy, Science and Technology: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Nuclear Energy Research and Development (AF)								
Operating	81.6	79.6	82.6	82.8	83.1	83.3	83.3	83.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction (Modifications to Reactors)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	1.0	1.5	1.5	1.5
Total	81.6	79.6	82.6	82.8	84.1	84.8	84.8	84.8
Direct Personnel	424.6	380.6	381.4	364.3	349.8	334.0	334.0	334.0
Uranium Programs (CD)								
Operating	1.1	0.2	1.2	0.6	0.6	0.6	0.6	0.6
Capital Equipment	0.0	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	0.0
Total	1.1	0.2	1.2	0.6	0.6	0.6	0.6	0.6
Direct Personnel	4.4	3.0	3.0	2.0	2.0	2.0	2.0	2.0
Program Direction - Nuclear Energy (KK-05)								
Operating	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Isotope Production and Distribution Program (ST)								
Operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Nuclear Energy, Science and Technology								
Operating	82.7	79.9	83.8	83.4	83.7	83.9	83.9	83.9
Capital Equipment	0.0	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	0.0
General Plant Projects	0.0	0.0	0.0	0.0	1.0	1.5	1.5	1.5
Total	82.7	79.9	83.8	83.4	84.7	85.4	85.4	85.4
Direct Personnel	429.1	383.9	384.4	366.3	351.8	336.0	336.0	336.0

Table VI.6 Energy Efficiency and Renewable Energy: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Solar and Renewable Resource Technologies (EB)								
Operating	5.0	4.4	6.3	6.3	6.3	6.3	6.3	6.3
Capital Equipment	0.2	0.1	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	0.0
Total	5.2	4.5	6.3	6.3	6.3	6.3	6.3	6.3
Direct Personnel	17.6	23.3	23.9	23.6	23.6	23.6	23.6	23.6
Building Technology, State and Community Sector (EC)								
Operating	0.8	0.9	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	0.0	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	0.0
Total	0.8	0.9	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	1.8	1.0	0.7	1.1	1.1	1.1	1.1	1.1
Industries of the Future (Specific) (ED-18)								
Operating	4.0	4.2	2.5	1.3	1.3	1.3	1.3	1.3
Capital Equipment	0.0	0.2	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	0.0
Total	4.0	4.4	2.5	1.3	1.3	1.3	1.3	1.3
Direct Personnel	12.9	21.1	14.2	7.3	7.3	7.3	7.3	7.3
Industries of the Future (Crosscutting) (ED-19)								
Operating	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Capital Equipment	0.0	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	0.0
Total	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Direct Personnel	3.2	4.9	4.5	4.6	4.6	4.6	4.6	4.6
Total Industry Sector (ED)								
Operating	4.9	5.1	3.4	2.2	2.2	2.2	2.2	2.2
Capital Equipment	0.0	0.2	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	0.0
Total	4.9	5.3	3.4	2.2	2.2	2.2	2.2	2.2
Direct Personnel	16.1	26.0	18.7	11.9	11.9	11.9	11.9	11.9

Table VI.6 Energy Efficiency and Renewable Energy: Resources by Subprogram (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Vehicle Technologies R&D (EE-05)								
Operating	15.8	21.0	26.8	26.4	26.4	26.4	26.4	26.4
Capital Equipment	1.9	1.6	2.0	1.7	1.7	1.7	1.7	1.7
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	17.7	22.6	28.8	28.1	28.1	28.1	28.1	28.1
Direct Personnel	74.5	94.2	104.1	106.2	106.2	106.2	106.2	106.2
Fuels Utilization R&D (EE-06)								
Operating	2.8	0.6	1.3	1.3	1.3	1.3	1.3	1.3
Capital Equipment	0.0	0.1	0.3	0.3	0.3	0.3	0.3	0.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.8	0.7	1.6	1.6	1.6	1.6	1.6	1.6
Direct Personnel	7.9	3.5	5.1	5.5	5.5	5.5	5.5	5.5
Materials Technologies (EE-07)								
Operating	1.5	1.4	2.4	3.0	3.0	3.0	3.0	3.0
Capital Equipment	0.1	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	0.0
Total	1.6	1.4	2.4	3.0	3.0	3.0	3.0	3.0
Direct Personnel	6.9	6.2	10.0	10.7	10.7	10.7	10.7	10.7
Technology Deployment (EE-08)								
Operating	1.1	1.2	1.3	1.3	1.3	1.3	1.3	1.3
Capital Equipment	0.0	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	0.0
Total	1.1	1.2	1.3	1.3	1.3	1.3	1.3	1.3
Direct Personnel	3.7	5.4	6.3	6.0	6.0	6.0	6.0	6.0
Implementation and Program Management (EE-09)								
Operating	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Capital Equipment	0.0	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	0.0
Total	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Direct Personnel	4.3	4.2	3.7	3.7	3.7	3.7	3.7	3.7
Total Transportation Sector (EE)								
Operating	22.2	25.2	32.8	33.0	33.0	33.0	33.0	33.0
Capital Equipment	2.0	1.7	2.3	2.0	2.0	2.0	2.0	2.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	24.2	26.9	35.1	35.0	35.0	35.0	35.0	35.0
Direct Personnel	97.3	113.5	129.2	132.1	132.1	132.1	132.1	132.1

Table VI.6 Energy Efficiency and Renewable Energy: Resources by Subprogram (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Policy and Management (EH)								
Operating	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	0.0	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	0.0
Total	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	1.2	0.7	1.1	1.1	1.1	1.1	1.1	1.1
Total Energy Efficiency and Renewable Energy								
Operating	33.2	35.8	43.1	42.1	42.1	42.1	42.1	42.1
Capital Equipment	2.2	2.0	2.3	2.0	2.0	2.0	2.0	2.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	35.4	37.8	45.4	44.1	44.1	44.1	44.1	44.1
Direct Personnel	134.0	164.5	173.6	169.8	169.8	169.8	169.8	169.8

Table VI.7 Fossil Energy: Resources by Subprogram ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Coal (AA)								
Operating	1.6	1.7	2.2	2.0	2.0	2.0	2.0	2.0
Capital Equipment	0.0	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	0.0
Total	1.6	1.7	2.2	2.0	2.0	2.0	2.0	2.0
Direct Personnel	5.5	9.3	9.7	8.2	8.2	8.2	8.2	8.2
Gas (AB)								
Operating	1.3	1.3	2.2	2.2	2.2	2.2	2.2	2.2
Capital Equipment	0.0	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	0.0
Total	1.3	1.3	2.2	2.2	2.2	2.2	2.2	2.2
Direct Personnel	11.6	8.9	11.4	9.6	9.6	9.6	9.6	9.6
Petroleum (AC)								
Operating	1.1	0.9	0.6	0.5	0.5	0.5	0.5	0.5
Capital Equipment	0.0	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	0.0
Total	1.1	0.9	0.6	0.5	0.5	0.5	0.5	0.5
Direct Personnel	0.4	5.1	3.8	3.2	3.2	3.2	3.2	3.2
Gas and Electricity (AU)								
Operating	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	0.0	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	0.0
Total	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	0.7	0.9	0.5	0.4	0.4	0.4	0.4	0.4
Fossil Energy Environmental Restoration (AW)								
Operating	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Strategic Petroleum Reserve (SA)								
Operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Table VI.7 Fossil Energy: Resources by Subprogram (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Total Fossil Energy								
Operating	4.1	4.2	5.1	4.8	4.8	4.8	4.8	4.8
Capital Equipment	0.0	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	0.0
Total	4.1	4.2	5.1	4.8	4.8	4.8	4.8	4.8
Direct Personnel	18.3	24.4	25.4	21.4	21.4	21.4	21.4	21.4

Table VI.8 Environmental Management: Resources by Subprogram ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Environmental Restoration and Waste Management — Defense (EW)								
Operating	7.5	5.9	6.4	5.7	5.7	5.7	5.7	5.7
Capital Equipment	0.1	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	0.0
Total	7.6	5.9	6.4	5.7	5.7	5.7	5.7	5.7
Direct Personnel	44.3	33.7	31.2	27.0	27.0	27.0	27.0	27.0
Environmental Restoration and Waste Management — Non-Defense (EX)								
Operating	22.7	23.0	12.2	15.6	9.6	3.0	3.0	3.0
Capital Equipment	0.0	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	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	22.7	23.0	12.2	15.6	9.6	3.0	3.0	3.0
Direct Personnel	81.1	82.8	39.9	38.5	38.5	12.0	12.0	12.0
Total Environmental Management								
Operating	30.2	28.9	18.6	21.3	15.3	8.7	8.7	8.7
Capital Equipment	0.1	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	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	30.3	28.9	18.6	21.3	15.3	8.7	8.7	8.7
Direct Personnel	125.4	116.5	71.1	65.5	65.5	39.0	39.0	39.0

Table VI.9 Defense Programs ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Weapons Activities (DP)								
Operating	5.5	2.6	1.7	1.6	1.5	1.5	1.5	1.5
Capital Equipment	0.4	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	0.0
Total	5.9	2.6	1.7	1.6	1.5	1.5	1.5	1.5
Direct Personnel	20.2	13.0	3.8	3.2	3.1	3.1	3.1	3.1

Table VI.10 Defense Nuclear Nonproliferation: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Fissile Materials Disposition (GA)								
Operating	1.8	1.7	1.7	1.8	1.8	1.9	1.9	1.9
Capital Equipment	0.0	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	0.0
Total	1.8	1.7	1.7	1.8	1.8	1.9	1.9	1.9
Direct Personnel	8.2	9.0	8.9	8.9	8.9	9.0	9.0	9.0
Nonproliferation and Verification R&D (GC)								
Operating	2.0	3.0	2.7	2.7	2.7	2.8	2.8	2.8
Capital Equipment	0.0	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	0.0
Total	2.0	3.0	2.7	2.7	2.7	2.8	2.8	2.8
Direct Personnel	8.1	10.8	9.5	8.9	8.9	8.8	8.8	8.8
Arms Control and Nonproliferation (GJ)								
Operating	16.1	13.8	21.9	24.6	17.9	17.3	17.3	17.3
Capital Equipment	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	16.4	14.1	22.2	24.9	18.1	17.5	17.5	17.5
Direct Personnel	51.7	56.7	67.6	64.5	58.4	55.0	54.7	54.7
International Nuclear Safety (VM)								
Operating	0.0	2.1	14.0	13.2	6.1	2.6	2.6	2.6
Capital Equipment	0.0	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	0.0
Total	0.0	2.1	14.0	13.2	6.1	2.6	2.6	2.6
Direct Personnel	4.0	7.4	23.5	23.6	12.6	5.8	5.8	5.8
Total Defense Nuclear Nonproliferation								
Operating	19.9	20.6	40.3	42.3	28.5	24.6	24.6	24.6
Capital Equipment	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	20.2	20.9	40.6	42.6	28.7	24.8	24.8	24.8
Direct Personnel	72.0	83.9	109.5	105.9	88.8	78.6	78.3	78.3

Table VI.11 Environment, Safety, and Health ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Environment, Safety, and Health — Non-Defense (HC)								
Operating	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	0.0	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	0.0
Total	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	2.3	3.3	3.0	2.9	2.9	2.9	2.9	2.9

Table VI.12 Policy ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Policy Analysis and Systems Studies (PE)								
Operating	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.7	1.4	1.1	1.1	1.1	1.1	1.1	1.1

Table VI.13 Economic Impact and Diversity ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Minority Economic Impact Program (WA-50)								
Operating	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.9	0.7	0.6	0.6	0.6	0.6	0.6	0.6

Table VI.14 Counterintelligence ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Counterintelligence (CN)								
Operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table VI.15 Federal Energy Regulatory Commission ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Federal Energy Regulatory Commission (VR)								
Operating	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	0.0	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	0.0
Total	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	0.0	0.5	0.6	0.6	0.6	0.6	0.6	0.6

Table VI.16 Intelligence ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Intelligence (IN)								
Operating	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	0.0	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	0.0
Total	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	1.8	1.8	2.2	2.2	2.1	2.0	2.0	2.0

Table VI.17 Security and Emergency Operations: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Nuclear Safeguards and Security (GD)								
Operating	0.4	1.3	0.2	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.1	0.1	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	0.0
Total	0.4	1.4	0.3	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2.7	6.0	1.2	0.0	0.0	0.0	0.0	0.0
Security and Emergency Operations[a] (SO)								
Operating	0.3	11.8	15.1	15.1	15.2	15.2	15.2	15.2
Capital Equipment	0.0	0.1	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	0.0
General Plant Projects	0.0	0.0	1.0	2.0	1.0	0.0	0.0	0.0
Total	0.3	11.9	16.1	17.1	16.2	15.2	15.2	15.2
Direct Personnel	0.0	3.1	94.9	94.8	94.8	94.5	94.5	94.5
Total Security and Emergency Operations								
Operating	0.7	13.1	15.3	15.1	15.2	15.2	15.2	15.2
Capital Equipment	0.0	0.2	0.1	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	0.0
General Plant Projects	0.0	0.0	1.0	2.0	1.0	0.0	0.0	0.0
Total	0.7	13.3	16.4	17.1	16.2	15.2	15.2	15.2
Direct Personnel	2.7	9.1	96.1	94.8	94.8	94.5	94.5	94.5

[a]Includes estimates for Safeguards and Security program.

Table VI.18 Work for Other DOE Contractors ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Operating	37.8	40.0	39.0	39.0	39.0	39.0	39.0	39.0
Capital Equipment	0.0	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	0.0
Total	37.8	40.0	39.0	39.0	39.0	39.0	39.0	39.0
Direct Personnel	154.7	109.2	93.3	75.4	65.9	59.0	57.5	44.7
Funds Transferred to Other DOE Contractors	-9.0	-11.0	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0

Table VI.19 Work for Others (WFO) Program ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
NUCLEAR REGULATORY COMMISSION								
Nuclear Regulatory Commission								
Operating	6.0	7.1	7.1	6.7	6.3	6.1	6.1	6.1
Capital Equipment	0.0	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	0.0
Total	6.0	7.1	7.1	6.7	6.3	6.1	6.1	6.1
Direct Personnel	24.6	28.7	26.9	23.2	20.4	19.7	19.7	19.7
DEPARTMENT OF DEFENSE								
U.S. Air Force								
Operating	1.6	1.8	2.0	2.0	1.4	1.4	1.4	1.4
Capital Equipment	0.0	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	0.0
Total	1.6	1.8	2.0	2.0	1.4	1.4	1.4	1.4
Direct Personnel	10.3	8.6	8.5	8.5	8.5	8.5	8.5	8.5
The Joint Staff								
Operating	4.9	2.0	1.0	1.0	1.0	1.0	1.0	1.0
Capital Equipment	0.0	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	0.0
Total	4.9	2.0	1.0	1.0	1.0	1.0	1.0	1.0
Direct Personnel	20.0	5.5	5.5	5.5	5.5	5.5	5.5	5.5
U.S. Army								
Operating	12.8	15.0	17.0	17.0	17.0	17.0	17.0	17.0
Capital Equipment	0.0	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	0.0
Total	12.8	15.0	17.0	17.0	17.0	17.0	17.0	17.0
Direct Personnel	51.6	52.3	52.0	52.0	52.0	52.0	52.0	52.0
U.S. Navy								
Operating	4.1	5.1	4.4	4.4	4.4	4.4	4.4	4.4
Capital Equipment	0.0	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	0.0
Total	4.1	5.1	4.4	4.4	4.4	4.4	4.4	4.4
Direct Personnel	17.4	17.5	17.5	17.5	17.4	17.4	17.4	17.4

Table VI.19 Work for Others (WFO) Program (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Defense Threat Reduction Agency								
Operating	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Defense Advanced Research Projects Agency								
Operating	2.6	3.1	3.7	4.3	4.0	4.0	4.0	4.0
Capital Equipment	0.0	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	0.0
Total	2.6	3.1	3.7	4.3	4.0	4.0	4.0	4.0
Direct Personnel	11.3	11.5	10.0	10.0	10.0	10.0	10.0	10.0
Other Defense								
Operating	0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Capital Equipment	0.0	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	0.0
Total	0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Direct Personnel	3.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total Department of Defense								
Operating	27.5	28.0	29.1	29.7	28.8	28.8	28.8	28.8
Capital Equipment	0.0	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	0.0
Total	27.5	28.0	29.1	29.7	28.8	28.8	28.8	28.8
Direct Personnel	118.8	97.9	96.0	96.0	95.9	95.9	95.9	95.9
OTHER FEDERAL AGENCIES								
Environmental Protection Agency								
Operating	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1
Capital Equipment	0.0	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	0.0
Total	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1
Direct Personnel	4.6	4.8	5.0	5.0	5.5	4.9	4.9	4.9

Table VI.19 Work for Others (WFO) Program (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Federal Emergency Management Agency								
Operating	5.0	4.6	1.5	1.5	0.8	0.8	0.8	0.8
Capital Equipment	0.0	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	0.0
Total	5.0	4.6	1.5	1.5	0.8	0.8	0.8	0.8
Direct Personnel	17.5	17.0	6.0	6.0	6.0	6.0	6.0	6.0
Department of State (International Atomic Energy Agency)								
Operating	1.8	1.5	1.8	1.8	1.8	1.8	1.8	1.8
Capital Equipment	0.0	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	0.0
Total	1.8	1.5	1.8	1.8	1.8	1.8	1.8	1.8
Direct Personnel	8.6	7.1	8.6	8.6	8.6	8.6	8.6	8.6
Department of Health and Human Services								
Operating	0.2	2.0	5.0	9.0	5.0	5.0	5.0	5.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.2	5.0	5.0	9.0	5.0	5.0	5.0	5.0
Direct Personnel	1.0	3.0	3.5	3.5	3.5	3.5	3.5	3.5
Department of Transportation								
Operating	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Department of Agriculture								
Operating	6.6	6.8	6.6	6.6	6.6	6.6	6.6	6.6
Capital Equipment	0.0	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	0.0
Total	6.6	6.8	6.6	6.6	6.6	6.6	6.6	6.6
Direct Personnel	23.3	20.0	20.0	20.0	20.0	20.0	20.0	20.0
National Science Foundation								
Operating	0.0	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Capital Equipment	0.0	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	0.0
Total	0.0	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Direct Personnel	0.0	3.2	3.0	3.0	3.0	3.0	3.0	3.0

Table VI.19 Work for Others (WFO) Program (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
National Aeronautics and Space Administration								
Operating	0.6	0.9	1.1	1.5	1.5	1.5	1.5	1.5
Capital Equipment	0.0	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	0.0
Total	0.6	0.9	1.1	1.5	1.5	1.5	1.5	1.5
Direct Personnel	2.1	1.4	0.8	0.8	0.8	0.8	0.8	0.8
Department of Commerce								
Operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Department of the Interior								
Operating	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	0.0	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	0.0
Total	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	4.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Other Agencies								
Operating	0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Capital Equipment	0.0	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	0.0
Total	0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Direct Personnel	0.6	1.8	1.3	0.4	0.4	0.4	0.4	0.4
Total Other Federal Agencies								
Operating	16.9	18.8	19.2	23.6	18.9	18.9	18.9	18.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	16.9	21.8	19.2	23.6	18.9	18.9	18.9	18.9
Direct Personnel	62.6	60.8	50.7	49.8	50.3	49.7	49.7	49.7
NONFEDERAL ORGANIZATIONS								
Electric Power Research Institute								
Operating	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table VI.19 Work for Others (WFO) Program (Cont.)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Private Firms								
Operating	5.1	9.2	9.0	9.0	9.0	8.9	8.9	8.9
Capital Equipment	0.0	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	0.0
Total	5.1	9.2	9.0	9.0	9.0	8.9	8.9	8.9
Direct Personnel	16.9	29.2	30.4	29.1	28.8	27.1	27.1	27.1
Universities and State and Local Governments[a]								
Operating	10.5	7.4	5.5	5.2	5.4	5.4	5.4	5.4
Capital Equipment	0.0	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	0.0
Total	10.5	7.4	5.5	5.2	5.4	5.4	5.4	5.4
Direct Personnel	34.8	18.5	20.9	24.5	24.5	24.5	24.5	24.5
International Organizations and Foreign Countries								
Operating	0.7	1.2	0.8	0.8	0.8	0.8	0.8	0.8
Capital Equipment	0.0	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	0.0
Total	0.7	1.2	0.8	0.8	0.8	0.8	0.8	0.8
Direct Personnel	2.3	2.4	1.8	1.8	1.8	1.8	1.8	1.8
Total Nonfederal Organizations								
Operating	16.3	17.9	15.5	15.2	15.4	15.3	15.3	15.3
Capital Equipment	0.0	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	0.0
Total	16.3	17.9	15.5	15.2	15.4	15.3	15.3	15.3
Direct Personnel	54.0	50.2	53.2	55.5	55.2	53.5	53.5	53.5
TOTAL WORK FOR OTHERS (WFO) PROGRAM								
Operating	66.7	71.8	70.9	75.2	69.4	69.1	69.1	69.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	66.7	74.8	70.9	75.2	69.4	69.1	69.1	69.1
Direct Personnel	260.0	237.6	226.8	224.5	221.8	218.8	218.8	218.8

[a]Most of these funds are from the University of Chicago for research supported by grants from the National Institutes of Health.

Table VI.20 Additional Work for Non-DOE Organizations[a] ($ in millions BA, personnel in FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
CRADA Partners[b]								
Operating	4.0	3.5	4.0	4.3	4.8	4.8	4.5	5.0
Capital Equipment	0.0	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	0.0
Total	4.0	3.5	4.0	4.3	4.8	4.8	4.5	5.0
Direct Personnel	17.4	23.0	26.0	28.0	32.0	32.0	30.0	33.0
Services to APS Users								
Operating	3.7	2.5	3.0	3.6	2.5	2.5	2.5	2.5
Capital Equipment	0.0	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	0.0
Total	3.7	2.5	3.0	3.6	2.5	2.5	2.5	2.5
Direct Personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Additional Work for Non-DOE Organizations								
Operating	7.7	6.0	7.0	7.9	7.3	7.3	7.0	7.5
Capital Equipment	0.0	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	0.0
Total	7.7	6.0	7.0	7.9	7.3	7.3	7.0	7.5
Direct Personnel	17.4	23.0	26.0	28.0	32.0	32.0	30.0	33.0

[a]Certain work performed by Argonne for non-DOE sponsors is not administered under the Laboratory's Work for Others (WFO) program and so is considered separately in this table. Included here are (1) funds received from cooperative R&D agreement (CRADA) partners and (2) funds received from collaborative access teams (CATs) at the Advanced Photon Source (APS) for services performed.

[b]Because of the difficulty in measuring meaningfully the BA (budget authority) associated with CRADA agreements, particularly multiyear agreements, the estimates in this section of the table are instead for actual expenditures and supported FTEs in the indicated years. Supported FTEs are exclusively programmatic.

Appendix: Argonne in an Integrated DOE Laboratory System

Cooperation among Argonne and the other DOE laboratories, particularly through direct R&D collaborations, continues to deepen. This integration of the DOE laboratory system is driven by several factors. The most pervasive is the emergence of new technologies that facilitate the long-distance communication needed for close coordination and now even allow some experiments to be controlled from anywhere in the United States. In response to new opportunities and accumulating experience, DOE managers increasingly are innovating with collaborative structures for the laboratories' performance of their programs. At the same time, experience and confidence with a widening range of collaborative approaches are accumulating at the laboratories. Seizing opportunities for increased interlaboratory collaboration and integration has been strongly endorsed by DOE advisory groups such as the Galvin Task Force and the external members of the Laboratory Operations Board.

A DOE R&D program can achieve effective integration across the national laboratories in different ways. The preferred approach depends largely on the nature of the science or technology development being undertaken and the distribution across the laboratory system of complementary R&D programs and other relevant capabilities. In simpler cases, a DOE program manager can achieve appropriate integration by first making nonduplicative project assignments that take advantage of the particular strengths of various laboratories and by then fostering sufficient communication among the laboratories so that their efforts remain coordinated. In other cases, greatly increased research productivity accrues when two or more laboratories work directly together on closely intermeshed projects or even on the same project. It is on these direct R&D collaborations among DOE laboratories that this discussion focuses. Laboratories that collaborate directly often enjoy considerable discretion to mutually choose research directions and complementary projects, within broad bounds set by the sponsoring DOE program office.

Table A.1 (presented at the end of this appendix) describes some of Argonne's more notable direct collaborations with other DOE laboratories. Brief summary descriptions in the table focus on the way effective collaboration is achieved. Not included are detailed discussions of the value of the research and of which laboratory does which tasks. The table also does not describe the many routine ways that DOE laboratories cooperate, as when one laboratory simply provides technical services to another on the basis of its special capabilities. Omitted as well are major Argonne R&D collaborations that involve only partners outside the DOE laboratory system, though many of the included collaborations do, as noted, extend outside the system to universities and industrial firms.

Particularly notable among the collaborations described in Table A.1 is the Spallation Neutron Source (SNS) to be built at Oak Ridge National Laboratory, the highest priority of DOE's Office of Basic Energy Sciences among new research facility construction projects. Construction of the SNS by pooling the capabilities of six national laboratories represents the largest collaboration of this kind that the Department has ever undertaken. Total project cost for the facility is $1.41 billion.

Table A.1 is misleading if it suggests that interlaboratory collaboration is a remarkable exception. In a number of program areas at Argonne, interlaboratory collaboration tends to be the rule.

Interlaboratory collaboration is a way of life for Argonne's nuclear physics program. Table A.1 includes two notable current collaborations in heavy-ion nuclear physics and accelerator development: (1) operation of the Gammasphere detector and (2) research aimed at developing an advanced accelerator for unstable nuclei. Another notable heavy-ion collaboration is the PHOBOS experiment at Brookhaven's Relativistic Heavy Ion Collider (RHIC). In medium energy nuclear physics, Argonne provides leadership in collaborative research at the Hall C experimental area of the Thomas Jefferson National Accelerator Facility, for which Argonne earlier constructed the 400-ton Short-Orbit Spectrometer. Argonne also collaborates extensively in Fermi National Accelerator Laboratory (Fermilab) experiments using high-energy lepton and hadron probes to measure quark distributions in nuclei. All of these experimental collaborations involve many university researchers. A major international collaboration in which Argonne represents the DOE laboratory system is construction of the RICH Detector for the HERMES experiment at Germany's Deutsche Elektronen Synchrotron (DESY).

In high energy physics, large collaborations have become a necessity over the last three decades. Driving this trend have been the increasing size, complexity, and cost of detectors and other projects, along with an associated decline in the number of facilities. Table A.1 includes the three detector collaborations in which Argonne currently is working directly with other DOE laboratories: (1) the ATLAS detector at Europe's CERN; (2) the MINOS detector, operated in conjunction with Fermilab; and (3) the long-standing Collider Detector at Fermilab (CDF). The CDF is notable for pioneering operational modes for very large international detector collaborations in high energy physics that originally had perhaps 300 members but today have as many as 1,700 (so that, for example, papers to be published are approved by all collaboration members and list all members as authors). As the current situation illustrates, Argonne's detector collaborations naturally include the host accelerator laboratory, which is often but not always a DOE laboratory. Argonne generally works closely with a group of universities to build a major detector component, while other laboratories lead the development of complementary components. Along with university partners, Argonne currently represents the DOE laboratory system in the large international ZEUS detector collaboration at DESY and in the Soudan 2 underground experiment located in Minnesota.

Argonne's computer scientists collaborate with many colleagues in other scientific and technical disciplines who face major computational challenges. Table A.1 features two such direct collaborations with other DOE laboratories, including (1) a "Clipper" project to develop advanced network capabilities for distributed applications and (2) an Advanced Visualization Technology Center for the large data sets that will be produced by the next generation of supercomputers. (See the heading "Science" for the first, "Defense Programs" for the second.) Other Argonne collaborations within the DOE laboratory system include work with Oak Ridge National Laboratory on coupled atmosphere-ocean models, work with Lawrence Livermore National Laboratory on automatic differentiation technology, and work with Los Alamos National Laboratory on advanced message-passing concepts. Argonne also participates in the Advanced Computing Technology Initiative, which is developing parallel numerical software tools that are being used by researchers at Los Alamos, Lawrence Livermore, and Lawrence Berkeley National Laboratories. Argonne computer scientists are also developing enabling technologies for advanced applications involving remote and distributed computing (URL: www.mcs.anl.gov/~pieper/ngi.html/). These applications include revolutionary improvements in security, fault tolerance, and networking capabilities for experiment planning, instrument operation, data reconstruction, and data analysis. This work involves direct collaboration with Lawrence Berkeley, Los Alamos, Lawrence Livermore, and Sandia National Laboratories, as well as several universities and research centers. (See Table A.1.)

Argonne is also leading the way toward new computational and communications technology that will facilitate even greater collaboration and integration across the DOE laboratory system. At the heart of this effort is research in advanced collaboration and software components technologies, which aims to develop new computational tools and libraries that will change fundamentally the way scientists work together, particularly from distant sites, and the way they address the major challenges of scientific computation. As Table A.1 describes, this work involves collaborations with six DOE multiprogram laboratories. Even more directly aimed at advancing future interlaboratory collaboration, within DOE and beyond, is a collaboration with Pacific Northwest National Laboratory on the development of new technologies that will make possible laboratories without walls — laboratories that unite expertise, instruments, and computers and ultimately enable scientists to carry out cooperative research without regard for geography. Argonne is also developing a virtual laboratory for exploring telepresence microscopy. (See Table A.1.)

It is important to recognize that R&D collaborations among DOE laboratories are often just the beginning of much broader collaborations with other federal agencies, universities, private companies, and organizations in other countries. A dramatic case in point is DOE's Atmospheric Radiation Measurement (ARM) Program, which includes collaborators supported by the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, and the National Science Foundation, as well as by government agencies in Canada, Australia, the United Kingdom, and Russia. (In Table A.1, see the next-to-final entry for the Office of Science.) ARM scientific investigations are conducted primarily by self-organized teams that submit proposals for peer review and work at a large field research site in the southern Great Plains (Oklahoma-Kansas). Two other large sites are located in the tropical western Pacific Ocean (between Indonesia and Christmas Island) and on the North Slope of Alaska. Of 49 science teams participating in the ARM Program, 43 are led by principal investigators from outside the DOE laboratory system. However, the DOE laboratories provide most of the research support: deploying and operating instruments, collecting and archiving data, and sending data to science team members.

Some DOE offices are pervasively organized to exploit the benefits of collaborative R&D. A leading example is the Office of Industrial Technologies, which is structured into industry teams under its "Industries of the Future" strategy. (In Table A.1, see the entries for Energy Efficiency and Renewable Energy.) For seven industries — chemicals, forest products, steel, aluminum, metal casting, glass, and agriculture — widely diverse collaborations among cost-sharing private companies and DOE laboratories are created to respond to important needs that industrial firms have targeted but lack the specialized capabilities and individual incentives to pursue. Through the Laboratory Coordinating Council and various subsidiary working groups, the DOE laboratories respond flexibly and creatively to industry needs, often working together on larger projects with industry where complementarity among the laboratories' capabilities can be exploited.

Direct collaboration among the multiprogram laboratories is the norm for work supported by the Nuclear Transfer and Supplier Policy Division within DOE's Office of Nonproliferation and National Security, illustrated in Table A.1 by the program Cooperation on Nuclear Export Controls in Russia and the Newly Independent States. In fact, virtually all of Argonne's work for this sponsor is conducted through close collaborations among multiprogram laboratories, and the work generally originates from project proposals developed jointly by the laboratories. Other current programs of this kind include Support to Multilateral Nonproliferation Regimes, Nuclear Export License Review, Technology Security, and Nonproliferation Workshops. Another major joint activity is development and maintenance of the Proliferation Network System, a database that serves to coordinate proliferation analyses among participating laboratories and the DOE sponsor.

In addition to R&D collaborations, Argonne works with other DOE laboratories to improve business and operations performance across a system of laboratories operated by universities, private corporations, and nonprofit organizations. A leading forum for this purpose is the National Laboratories Improvement Council (NLIC), which includes management representatives from all major DOE laboratories, plus key representatives from DOE. Since 1992, the NLIC has helped to organize, plan, and support improvement initiatives in business and operations areas and has fostered sharing of best business practices and lessons learned. Current initiatives aim at closer integration of the laboratories into DOE strategic planning, consistent incorporation of performance-based management principles into the contracts between DOE and laboratory operators, and more effective communication of the laboratories' accomplishments and their value.

Table A.1 Argonne's Direct Collaborations with Other DOE Laboratories and Beyond

DOE Program	Argonne's R&D Partners — National Laboratories; Others	Total DOE Program Funding (FY 2000)	Joint Roles of DOE Laboratories	Collaboration Highlights and Innovations
SCIENCE				
Spallation Neutron Source (SNS) construction project, supported by the Office of Basic Energy Sciences. Design and construct a new accelerator-based facility providing the world's most intense pulsed neutron beams for scientific and industrial R&D. The total project cost of this facility, which is being built at Oak Ridge National Laboratory, is $1.41 billion.	Brookhaven, Lawrence Berkeley, Oak Ridge, Los Alamos, Thomas Jefferson National Accelerator Facility. The neutron user community, including universities and industrial firms, plays a key advisory role.	$118 million	As a group, advise DOE on program directions through the Basic Energy Sciences Advisory Committee. Jointly recommend particular project elements to DOE. Meet approximately every six weeks for in-depth technical coordination on the entire facility construction project.	A new collaborative approach to designing and constructing a major DOE research facility, intended to be a model for future facilities. Each collaborating laboratory is responsible for integrating a major component — ion source, linac, accumulator ring, target, or instrumentation — into the final facility. In addition to taking advantage of each laboratory's distinctive strengths during construction, the new approach will facilitate the eventual shift at the Oak Ridge site to an operations staff with appropriate skills.
Linac Coherent Light Source (LCLS) Research Collaboration, supported by DOE's Division of Materials Sciences — at Argonne through the Advanced Photon Source. The collaboration will conduct R&D preparatory to construction of the LCLS, the first free-electron laser test facility in the hard X-ray spectral range. The ultimate goal is the concept for a fourth-generation light source user facility capable of performance greater than that of today's third-generation sources by many orders of magnitude.	Brookhaven, Lawrence Livermore, Los Alamos, Stanford Linear Accelerator. University of California at Los Angeles.	$1.5 million	Jointly advise DOE on overall program directions. Coordinate to select complementary research activities, subject to DOE approval. Achieve technical coordination across organizations through a quarterly meeting, plus frequent communication between individual investigators as needed.	The LCLS Research Collaboration will lay the groundwork for future cooperation among DOE laboratories in developing new synchrotron radiation facilities, including eventually the fourth-generation light source.
Isolated and Collective Phenomena in Nanocomposite Magnets, a technical project within the DOE Center of Excellence for the Synthesis and Processing of Advanced Materials, which was established by the Office of Basic Energy Sciences, Division of Materials Sciences, in partnership with the DOE laboratories. Improve materials for permanent magnets through improved understanding of the relationship between microstructure and magnetic properties.	Brookhaven, Lawrence Berkeley, Oak Ridge, Idaho Engineering and Environmental, Los Alamos. Ames Laboratory. Industrial manufacturers of permanent magnets.	Approximately $3 million for the Center of Excellence for the Synthesis and Processing of Advanced Materials	Coordinate to establish appropriate research areas. Mutually select technical approaches that best exploit and integrate the distinctive capabilities of the laboratory partners. Communicate all useful information quickly. Exchange experimental samples for characterization by techniques available at partner laboratories.	The DOE Center of Excellence for the Synthesis and Processing of Advanced Materials was designed specifically as a distributed organization dedicated to promoting a limited number of coordinated, cooperative multilaboratory research partnerships related to the synthesis and processing of advanced materials for energy technologies. After a finite life of five years within the center, a project is expected to have an established research agenda and associated collaborations and to become a normal DOE program that does not require such intense nurturing. DOE laboratory coordinators for the center's various projects have major input into long-run directions for the center, along with an industry steering group that also helps to review ongoing projects.

Table A.1 Argonne's Direct Collaborations with Other DOE Laboratories and Beyond (Cont.)

DOE Program	Argonne's R&D Partners — National Laboratories; Others	Total DOE Program Funding (FY 2000)	Joint Roles of DOE Laboratories	Collaboration Highlights and Innovations
Microstructural Effects on Mechanics of Materials, a project within the DOE Computational Materials Science Network, established by the Office of Basic Energy Sciences, Division of Materials Sciences, in partnership with the DOE laboratories. The goal is to elucidate and improve the mechanical properties of polycrystalline materials through improved understanding of the way dislocations interact with grain boundaries during deformation.	Lawrence Berkeley, Oak Ridge, Pacific Northwest, Lawrence Livermore, Los Alamos, Sandia. National Institute of Standards and Technology. MIT, University of Pennsylvania, University of California at Berkeley, Carnegie-Mellon University.	Approximately $1.1 million	Coordinate to establish appropriate joint research areas involving large-scale, massively parallel computer simulations. Mutually develop and select computer simulation approaches that best exploit and integrate the distinctive capabilities of the partner laboratories. Share all useful information quickly.	The DOE Computational Materials Science Network was designed specifically as a distributed research organization dedicated to promoting closely coordinated, cooperative multilaboratory projects involving large-scale, massively parallel computer simulations of advanced materials. Multilaboratory collaborations are at the heart of the network's strategy for developing new computational approaches to solving important, technologically relevant materials problems.
Materials Collaboratory, jointly supported by three DOE offices: Basic Energy Sciences; Mathematical, Information, and Computational Sciences; and Energy Efficiency and Renewable Energy. An interactive "virtual" laboratory on the Internet for consulting with colleagues and applying at a distance the characterization tools used for materials research.	Lawrence Berkeley, Oak Ridge. University of Illinois at Urbana-Champaign. National Institute of Standards and Technology of the Department of Commerce. Many industrial partners.	$3.0 million	Advise DOE on long-run program directions through a steering committee. Select mutually complementary projects to be undertaken. Coordinate standards and protocols for all R&D partners. Conduct weekly videoconferences on technical issues and program management.	The partners develop, test, procure, and define hardware and software for remote collaboration, focusing on microscopy and microanalysis.
Development of high-gradient superconducting accelerating structure technology for high energy physics and fourth-generation light sources, a collaboration stemming from a larger technology development collaboration centered at Germany's DESY. Supported by the Office of Science. The two DOE laboratories in Illinois plan to share the infrastructure required to adapt the DESY technology to their respective specialized interests and ultimately to serve other applications across the DOE system.	Fermilab. (Roughly 40 institutions worldwide participate in the large DESY-centered collaboration, including Argonne, Fermilab, and two U.S. universities.)	Argonne's participation supported by Laboratory-directed resources at this early stage	Advise DOE jointly on general issues and individually on applications (Fermilab for high energy physics, Argonne for fourth-generation light sources). Meet weekly for scientific and engineering discussions and monthly for longer-term planning of the substantial new infrastructure needed.	The long-run objective is to develop for the entire DOE laboratory system a coordinated capability in superconducting accelerator technology that will rely on collaboration with other DOE laboratories as its standard mode of operation.

Table A.1 Argonne's Direct Collaborations with Other DOE Laboratories and Beyond (Cont.)

DOE Program	Argonne's R&D Partners — National Laboratories; Others	Total DOE Program Funding (FY 2000)	Joint Roles of DOE Laboratories	Collaboration Highlights and Innovations
Research in distributed and remote computing, supported by DOE's Mathematical, Information, and Computational Sciences Division. Goals are to integrate and test advanced network technologies, to explore remote visualization of simulation results, to improve telepresence for major scientific instrumentation systems, and to develop the infrastructure needed for managing huge data sets.	Lawrence Berkeley, Lawrence Livermore, Los Alamos, Sandia. (Involvement depends on the specific project.) The National Center for Atmospheric Research. Seven universities.	$2.8 million (for Argonne only)	Select mutually complementary projects to be undertaken. Coordinate efforts to ensure compatibility of grid-related developments and to test, on applications across heterogeneous environments, the "middleware" being developed.	Middleware services developed by various projects of the Next-Generation Internet initiative will enable a new class of network applications. Results will be evaluated in various collaborative DOE science applications, including combustion, Earth systems, and particle physics.
U.S. participation in development of the *ATLAS detector for the Large Hadron Collider (LHC)* to be built at the CERN laboratory in Switzerland. U.S. participation is funded by DOE's High Energy Physics Division and by the National Science Foundation (NSF). By observing particle collisions at energies seven times greater than previously possible, investigate major physics questions such as the mechanism for electroweak symmetry breaking.	Brookhaven, Lawrence Berkeley. Approximately 25 universities.	$15 million	With university partners, advise DOE as a group through the ATLAS Executive Committee. Coordinate to develop mutually complementary detector components, subject to DOE approval.	This collaboration is notable for including large numbers of institutional and close individual collaborators (even for high energy physics), provision of sizable funding through both DOE and NSF, and an absolute constraint imposed by Congress on total U.S. funding for ATLAS and a second LHC detector. DOE and NSF coordinate funding and management through an innovative joint oversight group to which the DOE laboratories have input through the two detector collaborations. Two levels of contingency funds cushion the absolute U.S. funding cap.
The *MINOS detector* for long-baseline neutrino oscillations, supported by DOE's High Energy Physics Division. Located in a mine in Minnesota, the detector will receive neutrinos emitted from Fermilab in Illinois after they have traveled 730 kilometers underground.	Fermilab. Several universities.	$7.0 million	Select mutually complementary technical approaches, subject to DOE approval. Coordinate closely on day-to-day research activities, often through an R&D task team with members from the two DOE laboratories and from universities.	Of modest size for high energy physics, this collaboration illustrates the effective functioning of procedures that have been refined over many years as the numbers of participants in detector collaborations have increased.

Table A.1 Argonne's Direct Collaborations with Other DOE Laboratories and Beyond (Cont.)

DOE Program	Argonne's R&D Partners — National Laboratories; Others	Total DOE Program Funding (FY 2000)	Joint Roles of DOE Laboratories	Collaboration Highlights and Innovations
Collider Detector at Fermilab (CDF), supported by DOE's High Energy Physics Division. The original high-transverse-momentum detector at the Tevatron collider is used to study particle production and dynamics at the world's highest collider energy, including the production of top and bottom quarks and possibly electroweak symmetry breaking.	Fermilab, Lawrence Berkeley. Several U.S. universities and research groups from Italy and Japan.	Approximately $10 million	Collaborate in CDF upgrading under overall Fermilab leadership. Share in or undertake individually a broad range of tasks, including design, tooling, and task management, with many participating physicists spending a substantial fraction of their time at Fermilab.	This project pioneered many of the now-accepted operational modes for international detector collaborations involving hundreds of high energy physicists. Distinct project construction and operations organizations, responsible for meeting budgets and schedules, are in creative tension with a collaboration organization focused on physics requirements, detector performance, and analysis and publication of results. Atop the physics collaboration is a governing council of institutional representatives that organizes four or five analysis groups for different areas of physics, within which researchers coordinate (e.g., share analysis techniques and prevent overconcentration on popular topics) and review one another's work. The council decides global questions such as collaboration membership and optimization of running conditions for one investigation rather than another.
Operation of *Gammasphere*, supported by DOE's Nuclear Physics Division. The world's most powerful gamma-ray detector for studying the structure of atomic nuclei, Gammasphere was moved to Argonne from Lawrence Berkeley National Laboratory and operated for 18 months. Gammasphere is now returning to Berkeley.	Lawrence Berkeley and other national laboratories.	$800,000	Within a collaboration of 21 institutions, designed, constructed, and tested the $23 million Gammasphere. Operate the detector (first at Lawrence Berkeley, now at Argonne) to take advantage of unique complementary accelerator facilities available at each site. Coordinate closely on the very complicated dismantling, moving, and reassembly. Contribute collaborators to many outside experimental teams using Gammasphere. Advise DOE on future directions through the DOE-NSF Nuclear Science Advisory Committee, joint program advisory committees, and other avenues.	The harmonious, efficient relocation of Gammasphere illustrates one way that national laboratories work together effectively as part of a larger system.
Research aimed at developing *a rare isotope accelerator facility* to provide intense beams of short-lived, unstable (radioactive) nuclei for research in nuclear physics and related fields. To be supported by DOE's Nuclear Physics Division.	Lawrence Berkeley (development of detectors and an advanced ECR [electron cyclotron resonance] ion source). Thomas Jefferson National Accelerator Facility (development of superconducting resonators). Oak Ridge National Laboratory (concepts for high-powered targets).	Funding largely laboratory directed at this early stage	Coordinate concepts for various components of the new accelerator facility. Advise DOE jointly on future directions through the DOE-NSF Nuclear Science Advisory Committee, various program advisory committees, and other avenues.	These collaborations are largely informal and laboratory directed at this early stage, indicating the initiative that the DOE laboratories take in exploiting the complementarity of their capabilities.

Table A.1 Argonne's Direct Collaborations with Other DOE Laboratories and Beyond (Cont.)

DOE Program	Argonne's R&D Partners — National Laboratories; Others	Total DOE Program Funding (FY 2000)	Joint Roles of DOE Laboratories	Collaboration Highlights and Innovations
Advanced collaboration and software components technology research, supported by the Mathematical, Information, and Computational Sciences Division. Design new mechanisms, interfaces, and modules that enable flexible interoperability of tool kits, codes, and advanced computing resources for mission-critical DOE problems.	Various projects involve Lawrence Berkeley, Oak Ridge, Lawrence Livermore, Los Alamos, and Sandia. University of Southern California. Aerospace Corp.	$950,000 (for Argonne only)	As a group, advise DOE on long-run program directions.	Various elements of these projects — such as developing interfaces between computational tool kits originating at different laboratories, exploring component-based approaches to large-scale optimization, using numerical kernels to enable code reuse, and creating functionality to support experiments in networked computing — clearly will facilitate future collaboration across DOE sites.
Clipper environment for high-speed distributed computing, supported by the Mathematical, Information, and Computational Sciences Division. In preparation for the next-generation Internet, develop the network components and services needed for applications in a distributed environment that require high-speed data flows and supercomputing; demonstrate these innovations in a test bed involving three DOE laboratories.	Lawrence Berkeley. Stanford Linear Accelerator Center.	$200,000 (for Argonne only)	Advise DOE jointly on program directions; mutually select complementary projects, subject to DOE approval. Communicate design information via shared web pages as well as normal electronic mail; meet formally every two months.	Collaborating DOE laboratories will be the first beneficiaries of resulting advances in distributed computing. Development of prototype applications is facilitated by much faster connections between the three laboratories, for example, via the National Transparent Optical Network and ESnet.
Fusion Energy Sciences. A program to acquire the knowledge base needed for an economically and environmentally attractive fusion energy source.	Oak Ridge, Pacific Northwest, Sandia. Princeton Plasma Physics Laboratory. University of Illinois, University of Wisconsin, University of California at Los Angeles, University of California at San Diego. General Atomics.	Approximately $230 million	Advise DOE on long-run program directions via steering committees. Selectively propose projects jointly to DOE. Coordinate with one another and with university and industrial partners through telephone conferences every week or two and through major annual meetings.	A "virtual technology laboratory" within the fusion community facilitates the coordination and review of programs. Video conferencing to replace formal meetings is being developed.
Atmospheric Radiation Measurement (ARM) Program, supported by DOE's Environmental Sciences Division. In order to better understand global and regional climate change, teams of scientists gather field measurements at several diverse sites around the world and develop models of the processes that control solar and thermal infrared radiative transfer in the atmosphere.	Brookhaven, Lawrence Berkeley, Oak Ridge, Pacific Northwest, Lawrence Livermore, Los Alamos, Sandia. National Renewable Energy Laboratory. Also 19 other government agencies, 5 private companies, 12 international organizations, 21 universities.	$40 million	Participate in science team research, including collaborations with researchers from many organizations. Beyond science team projects selected by formal peer review, advise DOE jointly on program directions through the ARM Management Team. Collaborate daily with other scientists on various functional teams and in various site management offices. Coordinate the participation of other R&D partners, especially in connection with field observations and the analysis of collaborative experiments.	A remarkably diverse collaboration, in terms of geographic dispersion, as well as numbers and types of organizations. Pursuing methods of data management and information exchange via the Internet that will facilitate future interlaboratory integration.

Table A.1 Argonne's Direct Collaborations with Other DOE Laboratories and Beyond (Cont.)

DOE Program	Argonne's R&D Partners — National Laboratories; Others	Total DOE Program Funding (FY 2000)	Joint Roles of DOE Laboratories	Collaboration Highlights and Innovations
Atmospheric Chemistry Program, supported by the Environmental Sciences Division. Advance information about the atmospheric environment, especially regional and continental chemistry and the fate of tropospheric trace chemicals related to energy production; conduct laboratory studies, theoretical investigations, numerical modeling, and collaborative field campaigns.	Brookhaven, Lawrence Berkeley, Pacific Northwest, Lawrence Livermore. Two other federal agencies, eight universities, two private companies.	$6.5 million	Participate in various projects selected by peer review and closely coordinate their execution, especially through one to four collaborative field experimental campaigns conducted each year. Advise DOE jointly or individually. Meet within special-interest groups of program participants two or three times each year.	Joint field work features use of the Battelle G-1 research aircraft. The program's web site, in addition to research project descriptions, will provide data sets and codes for numerical atmospheric models.
NUCLEAR ENERGY, SCIENCE AND TECHNOLOGY				
Nuclear Reactor Technology Lead Laboratories, to be supported by the Office of Nuclear Energy, Science and Technology. Maintain the staff, facilities, and knowledge base required for future U.S. R&D on advanced nuclear reactors.	Idaho Engineering and Environmental; additional laboratory partners for specific projects.	Funding for FY 2001 being considered	Advise DOE jointly on the full range of R&D needed to support the future of civilian nuclear power. Jointly evaluate new reactor technologies. Organize and host a wide variety of meetings on technical issues, including international forums.	The two laboratories have proposed about a half-dozen major collaborative nuclear energy research projects on which their researchers would work together closely. Also anticipated is joint preparation of a road map to guide R&D on the next generation of nuclear power systems technology.
ENERGY EFFICIENCY AND RENEWABLE ENERGY				
High-Temperature Superconducting (HTS) Wire Development, three coordinated CRADAs supported by the Office of Electric Energy Systems and Storage. Development and fabrication of novel HTS conductors for electric power systems.	Oak Ridge, Los Alamos. University of Wisconsin at Madison. American Superconductor.	$850,000 (for the DOE laboratories only)	Advise DOE jointly regarding long-run program directions through the Wire Development Group, a formally constituted advisory body with broader responsibilities that meets every four months. Coordinate to select complementary research projects and responsibilities, under the leadership of American Superconductor and subject to DOE approval. Use monthly teleconferences and numerous intervening communications among researchers for immediate technical coordination.	Synergy among the DOE laboratories most often involves preparation, characterization, and testing of HTS samples at multiple locations. The Wire Development Group has effectively fostered other important DOE interlaboratory collaborations.
"Industries of the Future" structuring of the Office of Industrial Technologies. A strategy for coordinating and facilitating R&D for energy-intensive materials and process industries, often through partnerships involving DOE laboratories.	All eight other DOE multiprogram national laboratories. National Renewable Energy Laboratory, Ames Laboratory, Federal Energy Technology Center, Savannah River Site, Y-12 Plant, Albany Research Center. Industry trade associations, professional societies, universities, other government agencies, and many industrial firms.	$144 million	Through the Laboratory Coordinating Council, meet and confer with industry and other potential partners, as well as with the DOE program office. Contribute to the industry-led, DOE-fostered process of creating R&D visions and road maps for seven major industry groups. Create broad R&D partnerships featuring industry cost sharing and often involving multiple DOE laboratories.	The Laboratory Coordinating Council is an important organizational innovation for developing exceptionally broad R&D partnerships between industry and the DOE laboratories, and beyond.

Table A.1 Argonne's Direct Collaborations with Other DOE Laboratories and Beyond (Cont.)

DOE Program	Argonne's R&D Partners — National Laboratories; Others	Total DOE Program Funding (FY 2000)	Joint Roles of DOE Laboratories	Collaboration Highlights and Innovations
Applied CarboChemicals CRADA within the Alternative Feedstocks Program of the Office of Industrial Technologies. Development of cost-competitive chemical feedstocks from renewable resources such as corn.	Oak Ridge, Pacific Northwest. National Renewable Energy Laboratory. The company Applied CarboChemicals, a CRADA partner.	Roughly $270,000 (for the DOE laboratories only)	Make joint recommendations to DOE on long-run program directions and particular projects to be undertaken. Coordinate the participation of CRADA partner Applied CarboChemicals. Maintain frequent communication and coordination on technical issues among all partners.	Among the first multilaboratory projects in applied development of a new technology; considered a model for later projects. Developed the first multilaboratory CRADA and licensing agreements, which have facilitated later similar efforts.
ENVIRONMENTAL MANAGEMENT				
Sixteen projects for the *Environmental Management Science Program* (EMSP), which is jointly sponsored by the Office of Environmental Management and the Office of Science. Basic research aimed at much better technical solutions to DOE's environmental cleanup problems.	Pacific Northwest. Savannah River Site. U.S. Navy's Naval Surface Warfare Center. More than a dozen universities.	$2.5 million for the 8 projects involving Argonne	Provide broad advice to EMSP (and other Environmental Management programs) through the Strategic Laboratory Council, which includes one representative from each DOE laboratory and facilitates information exchange across institutions, as well as assisting EMSP in other ways, such as organizing joint conferences and workshops. Among R&D partner bench scientists, coordinate once or twice a month.	EMSP is a premier case of integration across sponsoring offices at DOE. Extensive collaboration among EMSP R&D partners is a core strategy, is explicitly encouraged by the program's proposal process, and is increasingly being implemented. An information network exploiting the Internet and other tools helps EMSP researchers communicate and collaborate beyond the program, with technology developers, managers of sites with environmental problems, regulators, and others. National workshops are held with potential DOE users of EMSP technologies.
Environmental Management programs (other than EMSP, described above). Environmental restoration, waste management, and associated technology development (including R&D, demonstration, testing, and evaluation projects) for DOE sites.	The multiprogram national laboratories. Ames Laboratory, Environmental Measurements Laboratory, Rocky Flats Environmental Technology Site, Savannah River Site. Many industrial firms and universities.	Approximately $15 million for Argonne alone, including R&D, technical support activities, and actual cleanup	Often advise DOE jointly on appropriate technical approaches, though the majority of R&D projects are selected by a straightforward process of proposals from individual laboratories. Through the Strategic Laboratory Council (as described above for EMSP), advise DOE on long-run R&D directions, program reviews and improvements, and strategic planning, including road maps. Among R&D partner bench scientists, coordinate weekly to monthly.	Technology demonstration projects are often very large in scale and accomplish major programmatic objectives in themselves. The demonstrations give an unusually wide range of technology providers and other collaborators the opportunity to prove themselves.
TechCon program, Office of Science and Technology. Provide technical assistance to private-sector waste management and environmental restoration project teams at DOE sites, for example by encouraging integration of commercial capabilities with emerging technologies.	Pacific Northwest. (Sandia coordinates the Innovative Treatment Remediation Demonstration program, which increasingly cooperates with TechCon.)	Approximately $1 million	Collaborate with DOE, site management private contractors, and subcontractors to identify opportunities to deploy superior remediation technologies to increase performance and reduce cleanup costs. Facilitate interactions among all parties, including stakeholders, helping to identify technology gaps and R&D needs.	TechCon employs (1) forums for multiple-site project vendors and (2) Internet project data gathering and interactions to reduce barriers to the implementation of innovative technologies, thereby achieving waste minimization, cost savings, performance improvement, and risk reduction. This unique mechanism assures integrated use of the best available environmental technologies for DOE site cleanups.

Table A.1 Argonne's Direct Collaborations with Other DOE Laboratories and Beyond (Cont.)

DOE Program	Argonne's R&D Partners — National Laboratories; Others	Total DOE Program Funding (FY 2000)	Joint Roles of DOE Laboratories	Collaboration Highlights and Innovations
Nuclear Materials Focus Area, supported by the Nuclear Material Stabilization Office. Identify and recommend solutions (including additional R&D) for technical and operational problems associated with the stabilization, long-term storage, and monitoring of nonweapons-grade plutonium surpluses and wastes.	Idaho Engineering and Environmental, Los Alamos, Sandia. Oak Ridge Y-12 Plant, Rocky Flats Environmental Technology Site, Savannah River Site. Bechtel BWXT Idaho, LLC (BBWI), Oxford Instruments.	Approximately $3 million for BBWI and Argonne	Coordinate the participation of private companies involved in product testing and validation. Selectively advise DOE jointly on long-run program directions (The two Idaho-based partners meet weekly for technical coordination.)	DOE-Environmental Management designed the "focus area" approach to provide a common framework for cooperation across DOE sites to attack common problems. In the past, for example, plutonium monitoring and surveillance systems (including ES&H and safeguards and security aspects) were implemented independently by each site.
DEFENSE PROGRAMS				
Nuclear Criticality Safety Program, supported by Defense Programs, Environmental Management, and other DOE offices. Establish within DOE an improved and integrated capability to predict criticality in nuclear fission systems through new experiments, benchmarking against available U.S. and international data, refinement of three alternative Monte Carlo computer models used within DOE, and processing of nuclear data into standard working forms.	Oak Ridge, Idaho Engineering and Environmental, Lawrence Livermore, Los Alamos. Two universities.	Approximately $9 million	As a group, advise DOE on long-run program directions. Work together on tasks such as evaluation of nuclear data, coordinating informally at the bench scientist level approximately every two months. Coordinate quarterly and annually to choose mutually complementary projects, subject to DOE approval.	Resulting information and software will be distributed in standardized form by the DOE-wide code center and will be easily used by engineers throughout DOE and beyond. For example, the refined nuclear criticality computer codes will be easily incorporated into the various laboratories' existing software systems.
Advanced Visualization Technology Center for Visualization SuperCorridors, supported by the Office of Defense Programs (DOE-DP) through the Accelerated Strategic Computing Initiative (ASCI). Develop breakthrough technologies that will enable the visualization, storage, and manipulation of large data sets for computational science and engineering produced by supercomputers performing trillions of operations per second.	Los Alamos and, in the future, other DOE-DP laboratories. University of Utah.	$1.25 million (for Argonne only)	The DOE-DP laboratories and ASCI alliance partners will apply test applications for software tools developed by Argonne and the University of Utah, which will manage the program day to day. All partners advise DOE jointly through a program advisory committee that includes all three DOE-DP laboratories, DOE program managers, and others.	Testing of applications requires close collaboration among all partners. Evolving procedures include weekly conference calls (involving entire research teams every other week) and very frequent electronic communication.

Table A.1 Argonne's Direct Collaborations with Other DOE Laboratories and Beyond (Cont.)

DOE Program	Argonne's R&D Partners — National Laboratories; Others	Total DOE Program Funding (FY 2000)	Joint Roles of DOE Laboratories	Collaboration Highlights and Innovations
NONPROLIFERATION AND NATIONAL SECURITY				
International Nuclear Safety Program (not including the research-oriented International Nuclear Safety Center, discussed below). Now supported by the Office of Nonproliferation and National Security. In cooperation with other Western industrialized countries and international agencies, conduct joint projects with eight former Soviet bloc countries hosting Soviet-designed nuclear reactors, to help correct major reactor safety deficiencies and establish a self-sustaining nuclear safety infrastructure.	Brookhaven, Pacific Northwest, Oak Ridge, Idaho Engineering and Environmental. Many U.S. engineering services and other companies.	$15 million	Coordinate and, within particular projects, participate either individually or as teams. Daily communication is typical among participating laboratories.	Special initiatives focus on reducing risks at the Chornobyl power plant, one unit of which (out of the original four) is still generating electricity. Participation in projects must go beyond other DOE-sponsored research organizations to include the host country (Russia, Ukraine, Armenia, Bulgaria, Czech Republic, Hungary, Lithuania, Slovakia, or Kazakhstan). DOE laboratory collaborators make extensive use of technologies such as videoconferencing and the paperless office.
International Nuclear Safety Center (INSC), now supported by the Office of Nonproliferation and National Security. For nuclear power engineering worldwide, promote the open exchange of safety information, cooperate in the development of safer technologies, and help collect and disseminate relevant information (particularly through a remotely accessible electronic database covering engineering information and results from safety analyses for U.S.-designed and Soviet-designed power plants and other nuclear facilities around the world).	Pacific Northwest, Idaho Engineering and Environmental. The Russian INSC, and through it more than ten Russian nuclear research institutes.	$0.5 million	Among U.S. researchers, coordinate monthly.	The U.S. INSC database and its Russian counterpart include the results of joint projects and are immediately accessible worldwide via the Internet. These on-line resources are very valuable in collaborations between the two countries.
Interior infrastructure preparedness component of the Chemical-Biological Nonproliferation Program, supported by the Office of Research and Development. Develop advanced technologies and technical services to help cities detect and counter the use of chemical or biological weapons by terrorists in subways, airports, high-threat buildings, and other places.	Lawrence Livermore, Los Alamos, Sandia. As this new program develops, partners will include engineering firms and emergency response organizations at all levels of government.	$1.9 million for the national laboratories	Advise DOE jointly on program directions, both informally and through a formal advisory group. Coordinate to choose mutually complementary projects, subject to approval by the DOE sponsor. Conduct joint R&D on topics such as simulating the impacts of chemical and biological releases.	Effective development and implementation of new technologies to address this complicated problem — such as detectors and computer models for predicting the transport and fate of chemical or biological agents — typically will require integration of expertise from multiple DOE laboratories and industry, plus close cooperation with city governments. Local transit authorities will cooperate in the program as appropriate and will support their own preparedness operations.

Table A.1 Argonne's Direct Collaborations with Other DOE Laboratories and Beyond (Cont.)

DOE Program	Argonne's R&D Partners — National Laboratories; Others	Total DOE Program Funding (FY 2000)	Joint Roles of DOE Laboratories	Collaboration Highlights and Innovations
Initiatives for Proliferation Prevention, supported by the Office of Arms Control and Nonproliferation. Identify and develop commercial nonmilitary work for scientists and engineers involved in weapons programs (nuclear, chemical, and biological) in the former Soviet Union (FSU), particularly by involvement of U.S. companies in cooperative R&D through DOE laboratories and ultimately in commercial deployment of FSU technologies.	All eight other DOE multiprogram laboratories. National Renewable Energy Laboratory, Kansas City Plant.	$22.5 million	Through the Interlaboratory Advisory Board, advise DOE on long-run program directions, recommend desirable projects to DOE, and oversee the participation of U.S. businesses. Coordinate formally on technical issues every two months, less formally approximately weekly. Use a Lotus Notes database on the World Wide Web to facilitate interlaboratory communication and informal program auditing by DOE.	Before involvement of U.S. companies, an R&D collaboration between a DOE laboratory and one or more FSU institutes is an opportunity to begin the education of FSU participants in intellectual property rights, entrepreneurship, and commercialization. To facilitate the collaborations, DOE has simplified project review processes and fostered implementation of uniform administrative procedures.
Nuclear Cities Initiative, supported by the Office of Arms Control and Nonproliferation. Identify and initiate commercial business opportunities that will employ former nuclear weapons workers in "closed" Russian cities, in order to help downsize the Russian nuclear weapons complex.	Lawrence Livermore, Los Alamos, Oak Ridge, Pacific Northwest, Sandia. (Initial negotiations have included many small businesses, as well as large companies such as Schlumberger and Motorola.)	$7.5 million (mostly passing through to Russian participants)	Advise DOE informally prior to project selection by DOE and project approval by the Russian Ministry of Atomic Energy (Minatom). Coordinate among laboratories through conference calls every two weeks and meetings twice a year.	Activities at each Russian city are coordinated by a lead DOE laboratory.
U.S./NIS Program of Cooperation on Nuclear Material Protection, Control, and Accounting (MPC&A), supported by the Office of Arms Control and Nonproliferation. In cooperation with Russia and the Newly Independent States (NIS), help strengthen security at sites in countries containing weapons-usable nuclear materials and assist in developing the countries' MPC&A systems.	Brookhaven, Oak Ridge, Pacific Northwest, Lawrence Livermore, Los Alamos, Sandia. Nonproliferation and National Security Institute, New Brunswick Laboratory, Pantex, Savannah River Site.	$150 million	Through the MPC&A Advisory Panel, provide technical recommendations to DOE on program plans and on project scopes, staffings, and budgets. Participate on multilaboratory teams undertaking particular projects, typically coordinating on technical issues at least weekly with team members at other laboratories. Coordinate the participation of other organizations, including FSU research institutes and private companies.	A typical large MPC&A project involves a very diverse set of tasks, to which several DOE laboratories logically contribute on the basis of their established special capabilities. Final implementation is in Russia or the NIS.
BN-350 Fuel Disposition, a project supported by the Office of Arms Control and Nonproliferation. To reduce proliferation concerns, develop safe, secure long-term storage for spent nuclear fuel assemblies now located at the BN-350 breeder reactor in Aktau, Kazakhstan. Cooperate with the reactor facility, a major research institute, and the Kazakhstan analog to the Nuclear Regulatory Commission.	Pacific Northwest, Los Alamos, Sandia. Nuclear Assurance Corp.	$16 million	Advise DOE jointly, as a group. Work toward harmonization of the tasks led by each laboratory. Provide technology, designs, and equipment in each laboratory's area of expertise. By electronic mail and telephone, coordinate daily on technical issues with partners at the other laboratories and in Kazakhstan.	The methods of communication used between technical experts in Kazakhstan and the United States are routine but effective, in part because similar backgrounds and interests foster a productive rapport.

Table A.1 Argonne's Direct Collaborations with Other DOE Laboratories and Beyond (Cont.)

DOE Program	Argonne's R&D Partners — National Laboratories; Others	Total DOE Program Funding (FY 2000)	Joint Roles of DOE Laboratories	Collaboration Highlights and Innovations
Cooperation on Nuclear Export Controls in Russia and the NIS, supported by the Nuclear Transfer and Supplier Policy Division. Help the NIS countries implement effective systems for controlling the export of materials, equipment, and technology that could be used to build nuclear weapons.	Oak Ridge, Pacific Northwest, Lawrence Livermore, Los Alamos, Sandia. Savannah River Site.	Approximately $3.0 million	As a group, make recommendations to DOE on long-run program directions and particular projects to be undertaken. Within each multilaboratory project team, coordinate each week with the other laboratories on technical issues. Coordinate the participation of NIS technical institutes.	The program is implemented largely through cooperative agreements directly between DOE laboratories and nine NIS technical institutes. These arrangements have greatly facilitated identification and training of the NIS technical experts needed by the government agencies administering nuclear export controls.
Mayak Spent Fuel Storage Project — Dry Storage, to be supported by the Office of Arms Control and Nonproliferation. Prevent further accumulation of separated civilian plutonium at the Russian RT-1 facility by addressing the lack of storage space for spent fuel, concentrating on a dry-storage approach.	Idaho Engineering and Environmental, Pacific Northwest.	$38 million requested for FY 2001	Advise DOE jointly on an informal basis. Collaborate directly on selected tasks where joint technical work is advantageous; in other areas, coordinate and share lessons learned.	Extended collaboration with U.S. industrial firms is possible.
International Center for Environmental Safety, to be supported by the Office of Nonproliferation and National Security. Work with the partner Russian center to resolve issues associated with the management of radioactive waste and spent nuclear fuel, decontamination of decommissioned nuclear facilities, and environmental restoration.	Idaho Engineering and Environmental.	$850,000 requested for FY 2001	Advise DOE jointly. Coordinate to exercise considerable discretion in selecting worthwhile projects, subject to DOE approval. For many projects, collaborate closely on technical tasks with each other and with Russian Center staff, with one of the two DOE laboratories serving as U.S. lead on each project.	International collaboration procedures being planned for this center would facilitate collaboration in other areas, such as (1) management of spent fuel and nuclear waste and (2) nonproliferation projects in the FSU.

Supplement 1: Work for Sponsors Other than DOE

Part of Argonne's work is supported by sponsors other than DOE. Major sponsors include the Nuclear Regulatory Commission, Department of Defense, Environmental Protection Agency, Federal Emergency Management Agency, Department of State, Department of Transportation, Department of Agriculture, National Institutes of Health, National Aeronautics and Space Administration, Defense Advanced Research Projects Agency, U.S. Navy, Department of the Interior, and private firms. (See Chapter VI for program funding.)

Argonne's work for non-DOE sponsors supports accomplishment of its missions (see Chapter II) and development of its initiatives (see Chapter IV). From a national perspective, this "work for others" (WFO) allows Argonne's unique facilities and capabilities to be applied to U.S. R&D priorities.

The Laboratory's WFO strengthens resources available for DOE missions and programs and promotes development of specific energy and environmental technologies. This WFO enhances Argonne's research capabilities, helps support the infrastructure at the Laboratory, and ultimately increases opportunities to transfer Argonne technologies to productive applications in the private sector. The Laboratory does not undertake work for non-DOE sponsors if that work can be performed satisfactorily by private organizations.

A. Nuclear Regulatory Commission

Argonne conducts research for the Nuclear Regulatory Commission (NRC) under a legislatively mandated memorandum of understanding between DOE and the NRC. Most of the Laboratory's work for the NRC has for many years involved supporting the Office of Nuclear Regulatory Research in its development of rules regarding plant safety and the condition of physical components. The largest efforts have addressed materials issues, steam generator tubing degradation, high-burnup fuel, and severe-accident behavior. Recently Argonne also began to (1) enhance environmental pathway models for analyzing the transport of residual radioactive contaminants and (2) develop parameters suitable for implementing NRC rules designed to assure public health and safety at nuclear facilities during the termination of licensed operations. In addition, Argonne provides technical assistance to the Office of Nuclear Reactor Regulation and to the Office of Nuclear Materials Safety and Safeguards.

Both the research and the technical assistance performed for the NRC take advantage of the Laboratory's special capabilities in nuclear reactor technology, technical evaluation, systems analysis, computer code development, environmental risk modeling, and assessment of environmental and health impacts. Argonne's work helps to ensure that U.S. nuclear power plants will continue their safe and efficient production of electricity without emission of carbon dioxide.

1. Office of Nuclear Regulatory Research

Argonne's materials research focuses on the degradation of structural materials in light-water reactors caused by reactor environments, including the effects of water chemistry and neutron irradiation. These studies include measurements of (1) growth rates of stress corrosion cracks and (2) the fatigue life of stainless and ferritic steels used in the reactor core, piping, and pressure vessel. Results from these studies are used by the NRC to ensure the structural integrity of plants as they age. The testing includes specimens from operating commercial reactors. Additional irradiations of stainless steels are performed in Norway's Halden test reactor to provide further systematic data on relationships between material composition and susceptibility to cracking after irradiation.

A comprehensive study of degradation in the steam generator tubing of nuclear power plants is under way. Critical areas being addressed include (1) evaluation of techniques used for in-service inspection of steam generator tubes and recommendations for improving the reliability and accuracy of those inspections, (2) validation and improvement of correlations for evaluating structural integrity and leakage of degraded steam generator tubes, and (3) validation and improvement of correlations and models for predicting degradation in aging tubes during operations. The studies focus on mill-annealed Alloy 600 tubing, but tests will also be performed on replacement materials such as thermally treated Alloy 600 and Alloy 690.

Argonne is investigating the behavior of high-burnup nuclear fuels for the NRC. To reduce operating costs and minimize the accumulation of spent fuel, nuclear utilities are striving to increase the burnup of their nuclear fuels, thus extracting more electricity from a given amount of fuel and reducing (1) the volume of the spent fuel requiring subsequent handling, (2) the number of refueling outages, and (3) plant downtime. Currently, utilities seek to achieve burnup roughly 50% higher than in the 1970s, when most of the NRC's criteria and codes for fuel behavior were established. However, at high burnups, fuel pellets and cladding are potentially less resistant to damage under some conditions. These considerations may necessitate modification of fuel rod damage criteria used in NRC regulations and of materials properties assumed in safety analyses. Furthermore, new alloys and fabrication procedures designed to counter burnup effects may also affect regulatory criteria and safety analyses. To help address these issues, Argonne is determining the behavior of high-burnup fuel under accident conditions where coolant is lost and is establishing a database for the mechanical properties of high-burnup cladding, which is needed for licensing safety analyses. The Laboratory is also investigating the way high burnup might affect cladding and the behavior of spent fuel during long-term dry storage, a strategy now being employed at the sites of many nuclear power plants.

The NRC continues to use Argonne's broad expertise in severe-accident phenomena. The Commission is a partner in the Melt Attack and Coolability Experiment Program, which is organized by the Electric Power Research Institute. The Laboratory's contributions to this program are described in Section S1.D.1.

The NRC License Termination Rule provides assurance of public health and safety at nuclear facilities during the termination of licensed operations. To support the development of implementation guidance for the Rule and an associated Standard Review Plan, NRC is supporting expansion of the Argonne software programs RESRAD and RESRAD-BUILD. The expanded programs will specifically address the cleanup of contaminated sites and buildings during the decontamination and decommissioning of facilities. The software was originally developed for DOE, to help analyze environmental remediation at DOE sites by modeling environmental pathways and the transport of residual radioactive contaminants. The new NRC work extends the existing models to include performance of probabilistic dose analyses, thereby allowing NRC licensees to demonstrate compliance with the License Termination Rule and supporting NRC evaluation of the licensees' applications for facility termination.

2. Office of Nuclear Reactor Regulation

Argonne assists the Office of Nuclear Reactor Regulation in a variety of areas related to aging and the performance of materials, components, structures, and systems in nuclear power plants. This work contributes to the development and updating of a standard review plan for operating reactors that is used by NRC staff to assess the suitability of extending a plant's original 40-year license for an additional 20 years.

Argonne provides technical support to the NRC in the resolution of generic license renewal issues involving phenomena such as fatigue of metal components, thermal fatigue of cast austenitic stainless steels, irradiation-assisted stress corrosion cracking, and irradiation-induced void swelling.

The Laboratory is reviewing aging effects and their management for nuclear plant systems, structures, and components that must meet license renewal rules. The resulting report and an associated standard review plan will serve as guidance documents for NRC reviews of license renewal applications. Argonne also provides various other kinds of technical support to the Office of Nuclear Reactor Regulation.

3. Office of Nuclear Materials Safety and Safeguards

For the Office of Nuclear Materials Safety and Safeguards, Argonne is modeling environmental and health effects from uranium recovery operations to help the NRC (1) deal with changes in regulatory requirements and (2) consider revisions of existing licenses and applications for new licenses for uranium mining and processing. Enhancements of the current model will take into account *in situ* uranium leaching technology and associated processing. A key issue is the transport of uranium and decay product radionuclides (including radon gas) and their associated environmental and health impacts. At the same time, the Laboratory is developing an Internet-based communication mechanism to facilitate distribution of the software code and the NRC's interaction with prospective licensees. Argonne is also helping the NRC's Uranium Recovery Branch prepare environmental assessments for license applications for *in situ* uranium mining in central Wyoming. These analyses consider impacts to the nearby ecology, cultural resources, air quality, transportation, land use, and the socioeconomic system.

B. Department of Defense

Argonne conducts research for several organizations within the Department of Defense (DOD).

1. Office of Secretary of Defense

As simulations of military operations become more accurate, the need for detailed data on terrain to support these simulations has grown dramatically. To provide the required input for the Program Analysis and Evaluation Office, Argonne is developing a sophisticated application for generation of synthetic terrain.

The Laboratory is developing components for the Joint Warfare System (JWARS), a comprehensive modeling and simulation system for analysis, planning, and acquisition. JWARS utilizes existing state-of-the-art models but adds new capabilities, including environmental effects and more comprehensive use of spatial data. An intelligent geographic information manager developed at Argonne will provide unique visualization capabilities by dynamically linking modeled data to various graphic analysis subsystems within JWARS. Argonne also assists in developing components for the Joint Warning and Reporting Network, using the Laboratory's maps and data browser (MaD) system to display active, vector-based spatial data from sensors and models.

2. Office of Strategic Computing and Simulation

Argonne participates in the Center on Astrophysical Thermonuclear Flashes (see Web location www.asci.uchicago.edu/), one of five Academic Strategic Alliances Program centers of the Accelerated Strategic Computing Initiative (ASCI). Argonne provides essential software for ensuring code portability and high performance.

In another ASCI project, Argonne is collaborating with university researchers and DOE-Defense Program laboratories in the development of technology for the visualization, storage, and manipulation of large-scale data sets produced from teraflops-speed supercomputers (see the Web location www.mcs.anl.gov/fl/research/proposals/avtc.html).

3. U.S. Air Force

The U.S. Air Force sponsors several programs at Argonne. The Laboratory's experience and expertise in conducting environmental assessments of sites with unique environmental features or unique potential impacts are being used for several major proposed Air Force activities.

Argonne is studying biodiversity at a number of Air Force installations across the country, focusing on the abundance of federal- and state-listed species and on the existence of exceptional natural communities. The information collected is incorporated into geographic information systems.

Argonne also studies a number of environmental systems to identify for the Air Force the most cost-effective technical approaches to environmental management. The Laboratory evaluates environmental quality systems for the Air Combat Command. For the Air Force Materiel Command, the Laboratory is developing innovative approaches to computer-assisted management of large numbers of air pollutant emission sources in complex industrial areas. The models being developed will contribute to risk management planning related to the storage and use of hazardous materials. New approaches for environmental management will shift the emphasis from compliance to pollution prevention. In addition, the Laboratory is assisting the Pacific Air Force and Space Command in its implementation of novel, cost-effective methods for carrying out environmental stewardship, including the management of cultural and natural resources at military installations in the United States and abroad.

For the Air Force Weather Agency (AFWA), Argonne is developing a theater weather forecasting and analysis capability aimed particularly at theater battle management. The focus is on the overall system architecture and the parallel implementation of selected software elements, which will support collaborative development of the system. This Global Theater Weather Analysis and Prediction System is now installed at the AFWA installation at Offutt Air Force Base, Nebraska. The forecasting model used by AFWA is a version of a mesoscale model originally developed by the National Center for Atmospheric Research (NCAR) and Pennsylvania State University. Argonne's parallel version of the model is widely used and is now provided by NCAR to the public domain. Argonne plans further development of the parallel forecasting model and development of a state-of-the-art analysis model. For regional weather analysis, the Laboratory is developing a capability to generate user-selected product mixes in real time from data supplied by a central computer. Argonne is also developing a computer-based tool for assessing the effects of weather on the operational capabilities of aircraft, weapons systems, and sensors.

Working directly with the Air Force, Argonne is developing an on-line consequence management information system. In addition to managing data, the system supports decision making by individual bases in preparation for and in response to a wide range of potential events, including accidents and natural disasters.

As an extension of an earlier project, Argonne is customizing an enhanced version of an advanced information tool to assist the Secretary of the Air Force, Office of the Inspector General, in handling requests made under the Freedom of Information Act.

4. The Joint Staff

Argonne supports the J-8 Directorate of the Joint Staff. This work entails developing better planning and simulation models and evaluating new or improved information management technologies. An important aspect of the work involves developing innovative uses of rapidly advancing graphics technologies to manipulate and analyze large databases. These Laboratory efforts take advantage of more than 15 years of experience in designing large engineering and scientific databases; developing new methods of representing data; and building and using knowledge bases, image exploitation, and data visualization. The work for J-8 also benefits from the availability of relevant advanced processors at Argonne's High-Performance Computing Research Facility, the Laboratory's extensive and diverse experience in applied decision analysis, and its experience in studying knowledge representation and applying expert systems.

Working with J-8, Argonne has greatly expanded its efforts to develop a modeling system for simulating and displaying environmental effects at Earth's surface. The resulting software system, the Dynamic Environmental Effects Model, supports both static and dynamic investigations of geographic areas. The system will have wide applicability, both within and outside J-8 and DOD. To provide the "synthetic environment" needed by the military for training and analysis, the model must manage and coordinate information based on natural (atmospheric and oceanic) processes and human disturbances (effects of vehicles and weapons). The model uses software objects intensively and is a sophisticated and comprehensive implementation of modern object-oriented theory. Initial development, pioneered by J-8 and Argonne, has already elicited interest and funding from the armed services and other DOD agencies.

Also for J-8, Argonne is pioneering the use of advanced information retrieval techniques in planning and decision support systems. Such systems integrate text management and data management technologies into a single platform for analyzing requirements for new acquisitions. In addition, the Laboratory is applying object-oriented techniques to mission planning. Associating image data with objects greatly enhances the quality of assessments. Argonne is using these tools to support the Joint Community in infrastructure assurance analyses and technical R&D evaluations. Other work for J-8 includes (1) development of a linear programming approach to optimizing the process of filling billets in units, in order to ensure combat readiness (allowing for rest periods, specialization, and training levels) and to preserve unit coherence and (2) design and implementation of a complex behavioral simulation for counter-drug applications.

Since 1987 the Joint Staff has sponsored a multifaceted logistics and mobility modeling program at Argonne. The program has two primary goals: (1) to provide decision makers with information management capabilities for planning missions such as military operations, disaster relief, and peacekeeping and (2) to develop advanced computer system prototypes for planning and tracking the movement of personnel, equipment, and supplies throughout the world. The program has grown to include 13 interrelated projects. One representative model simulates detailed logistic movements that begin with arrivals at ports (by sea or air) and includes movements across land (by road, rail, inland water, or air) through various intermediate destinations to a final set of destinations. Movements of people, supplies, and equipment are included. Other Argonne models address the same kinds of movements at different levels of detail. A more aggregated model determines the maximum amount of material that can be pushed through an infrastructure network in a given time period. On the other hand, a highly disaggregated model simulates each process that occurs at a seaport (unloading, handling, and waiting) at a much greater level of detail. Also being modeled is the commercial energy infrastructure at DOD sites, including natural gas and oil systems. As part of the overall effort, deployment operations at Army installations are being simulated.

Argonne is intensely involved in the design and implementation of high-performance networks incorporating the latest switching technologies, to support both classified and unclassified network implementations with a high degree of flexibility. Designs provide for multimedia connectivity worldwide via the Internet and the Defense Simulation Internet. Current efforts in this area extend from the J-8 Directorate and the Joint Staff to the U.S.-Republic of Korea Combined Forces Command and Central Command components. Long-range plans provide for phased implementation of higher-performance technologies as they evolve.

5. U.S. Army

Argonne assists the Army's implementation (in conjunction with the Federal Emergency Management Agency) of the Chemical Stockpile Emergency Preparedness Program (CSEPP). The Laboratory supports program development, policy analysis and development of associated guidance, emergency preparedness planning, institutional analysis, development of hazard-specific risk communications and emergency public education mechanisms, and testing and assessment of response capabilities. Argonne also assists in technical management. This work involves hazard analysis; modeling of chemical agent dispersion; development of cost estimation and measurement methodologies; integration for emergency planning; and collection, analysis, and validation of meteorological data at each of the CSEPP installations.

For the Army Environmental and Engineering Commands, Argonne is conducting research at a series of demonstration sites to develop techniques for environmental rehabilitation of U.S. Army training bases in the continental United States and Europe. The focus is on developing site-specific recommendations for training sites that will serve as models for other installations, thereby facilitating integration of training needs with environmental management.

For the Waterways Experiment Station of the Army Corps of Engineers, Argonne has provided advanced visualization software to support field sampling; the Laboratory is currently a partner in the Groundwater Modeling System Program. For the Fort Worth District of the Army Corps of Engineers, the Laboratory conducts specialized environmental analyses for water resources projects.

Argonne also helps the Army Corps of Engineers implement projects under Superfund and the Defense Environmental Restoration Program through the Kansas City District. The Laboratory is developing specialized approaches to remedial investigations and feasibility studies, particularly for sites with risk of radiological contamination.

Argonne assists several districts of the Army Corps of Engineers in the efficient execution of the Formerly Utilized Sites Remedial Action Program, which was transferred from DOE to the Corps in FY 1998. The Laboratory brings specialized technical capabilities to this cleanup program, including the Adaptive Sampling and Analysis Program (ASAP), the RESidual RADioactivity (RESRAD) code for dose assessment and determination of cleanup criteria, and advanced tools for management of environmental data.

Argonne is conducting an integrated program of environmental and engineering research and technical support for the Army Corps of Engineers (Mobile District) and the Army Environmental Center, examining issues such as land restoration, solid waste management, site characterization, and cleanup of hazardous waste sites.

For the Army Soldier and Biological Chemical Command, Argonne assists in the development and analysis of restrictions regarding the land disposal of chemical agents and their by-products in the environment. Studies are coordinated with multiple environmental agencies within the Army and with several states. The Laboratory also supports the Command's Assembled Chemical Weapons Assessment Program in the area of environmental compliance for demilitarization of assembled munitions by exploring alternatives to incineration of material from the U.S. chemical agent stockpile. In addition, Argonne is employing models and analyses to address environmental management issues at the Command's Rocky Mountain Arsenal, Pueblo Depot Activity, and Aberdeen Proving Ground.

Argonne provides technical assistance for environmental restoration activities at the Aberdeen Proving Ground, which has a legacy of chemical contamination. The Laboratory is seeking solutions to such problems through a restoration study at the "J Field" site and through sitewide remote sensing. Work addresses management of environmental information, wetlands issues, and the natural attenuation of groundwater contamination.

Argonne has undertaken studies of the environmental risks posed by active and former test ranges for the Army Developmental Test Command. Argonne is now conducting specific environmental restoration and compliance assessment studies at several installations of the Command (Dugway Proving Ground, Yuma Proving Ground, and White Sands Missile Range).

Argonne supports the Army Environmental Center through R&D on environmental restoration at various Army installations, including several sites that have been placed on the National Priorities List. Specific activities include development of state-of-the-art environmental data management systems to expedite remedial decision making and use of groundwater and soil gas models to evaluate alternative methods of restoring aquifers. The Laboratory is also supporting compliance and regulatory analyses for the Center, including critical issues related to the Range Rule, which addresses public health and safety risks due to used munitions.

For the U.S. Army Defense Ammunition Center (USADAC), a part of the Industrial Operations Command (IOC), the Laboratory is developing a data system for hazardous waste characterization to support environmental compliance related to the destruction of munitions and explosives at Army installations and to the reuse and recycling of components. In related efforts, Argonne is developing a demilitarization planning and management system that incorporates the USADAC system and other information to improve the Army's ability to plan for cost-effective and environmentally sound demilitarization. In addition, the Laboratory performs specialized environmental modeling and data analyses to address radiological risk and restoration problems at IOC installations (Letterkenny, Long Horn, and Seneca). The Laboratory is also developing the Joint Munitions Planning System, an advanced technology simulation tool for managing the global distribution of munitions.

Modeling and simulation to support adaptive management of ecosystems is accomplished best through a dynamic, integrated, flexible approach that casts appropriate science and technology components into a comprehensive ecosystem modeling framework. For the Army, Argonne is developing the Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS), which integrates ecological models, decision support techniques, and a geographic information system to provide the tools required for effective management of impacts due to training operations. This work is funded through the DOD Strategic Environmental Research and Development Program.

6. U.S. Navy

For the Executive Agent for Modeling and Simulation of the Ocean, Argonne is using its environmental representation technology to build a littoral-zone simulation of wave action, including simulation of near-shore currents and bottom scouring.

The Laboratory supports the Naval Facilities Command and the Civil Engineer Corps Officer School in the area of ecological risk assessment, in part by transferring to the Navy restoration program the ecological risk assessment methodologies developed for DOE cleanup programs and also by developing information management systems to increase the efficiency of responses to ecological risk assessments.

For the Naval Surface Warfare Center, Argonne is developing and evaluating a long-distance chemical agent detector with no moving parts that is based on acousto-optical tunable filters and infrared microbolometer arrays. This instrument will provide a video image of a target, along with spectroscopic information for determining automatically whether a plume contains a chemical agent.

7. Defense Threat Reduction Agency

As part of its arms control program, Argonne develops verification and validation procedures for the Defense Threat Reduction Agency. Currently the Laboratory is studying the overall, long-term information and organizational requirements for treaty verification and compliance as further treaties are implemented. These efforts include analysis of functional requirements; technical evaluation, independent verification, and validation of new automated systems; prototyping for automated training techniques; and assistance in implementation planning. The Laboratory is also performing studies and technical evaluations in support of the Open Skies Treaty and assists the Technology Applications Directorate with emergency preparedness reviews and training at civilian and military facilities.

8. Defense Advanced Research Projects Agency

For the Defense Advanced Research Projects Agency, Argonne is using microchip technology, which it developed earlier for DOE's Human Genome Project, as the basis for fast, reliable detection of biological warfare agents. Armed with many different gel-immobilized oligo-nucleotides, one tiny glass chip will, in just minutes, detect and identify viruses, bacteria, and genes that code for protein toxins. The gel test medium allows multiple layers of receptor compounds to be stacked on the microchip for greater sensitivity. The long-term goals are to provide soldiers in the field with simple equipment that rapidly detects biological warfare agents and to design more complex field laboratory equipment capable of detailed analyses.

Because of the success of its Logistics and Mobility Modeling Program, Argonne has been selected as lead agency for simulations in the Advanced Logistics Program. The simulation area is a distinctive Argonne competency that includes advanced simulation, visualization tools, and algorithms for parallel computation; automated reasoning; and object-oriented databases. That competency contributes significantly to the Advanced Logistics Program. Of particular interest are several high-fidelity simulations of transportation and logistics processes that Argonne has developed over the last decade. Argonne is integrating these simulations into a new type of cluster software architecture that combines simulation and scheduling technology with real-time data feeds on the locations and status of various items. The result will be a unique view of the past, the present, and projected states of readiness in the logistics support infrastructure. The system will replan logistics, dynamically and continuously, in response to rapidly changing conditions.

As part of the Globus project, Argonne researchers are developing software for geographically distributed computations (see the Web location www.globus.org). Under way as well is a project to develop oxide thin film technology for radar and communications systems.

C. Other Federal Agencies

1. Environmental Protection Agency

Argonne researchers are working with the U.S. Environmental Protection Agency (EPA) to develop a geographic information system to help analyze data on hazardous and toxic substances found at sites designated for cleanup under the Superfund Authorization and Recovery Act. Displaying the data to highlight geographic aspects is a particular interest.

Through the Environmental Technology Initiative, jointly funded by DOE and EPA, regulatory prototypes for the petroleum refining industry that were identified and evaluated by Argonne are being put in final form for publication.

Argonne provides analytical support to the Global Change Division regarding industrial technologies and new policies that may mitigate emission of greenhouse gases. The Laboratory is studying industrial cogeneration and other technology options and analyzing scenarios involving high industrial energy efficiency, by using the National Energy Modeling System and the Argonne Multisector Industry Growth Assessment Model.

For the EPA Office of Air Quality Planning and Standards, Argonne is developing improved methods for estimating the deposition of hazardous air pollutants with the Industrial Source Complex model. Dry and wet deposition to Earth's surface during short-range transport and dispersion from individual sources is described in terms of meteorological conditions, substance properties, and characteristics of the underlying surface.

For the EPA Office of Pollution Prevention and Toxics and EPA Region V, Argonne is extending methods of analyzing cumulative environmental risks in urban areas by enhancing the availability and performance of scientifically sound procedures, models, analytical tools, and guidelines. One objective is to identify areas within the metropolitan Chicago region where exposures of the general population to individual pollutants or combinations of pollutants might be significant.

To calculate radionuclide slope factors useful in predicting incremental cancer risks due to exposure to low levels of radioactive materials, Argonne is assisting the EPA with documentation and implementation of revised radiation dosimetry and risk analysis methods. In addition, Argonne provides guidance documentation, training materials, and fact sheets for the EPA *Radiation Exposure and Risk Assessment Manual*.

2. Federal Emergency Management Agency

Argonne's support to the Federal Emergency Management Agency involves three major areas relating to accidental or deliberate releases of radiological and hazardous materials: (1) analysis and evaluation of the capabilities of U.S. industry, nearby communities, and host states to respond to emergencies involving the materials; (2) R&D on guidance for emergency planning, exercises to test emergency plans, and response activities; and (3) the development and conduct of training activities in support of area 2.

3. Department of State and International Atomic Energy Agency

Throughout most of its existence, Argonne has actively supported the worldwide transfer of peaceful applications of nuclear technology. Shortly after the Laboratory was founded, the first international training activities were established as part of the Eisenhower Atoms for Peace program. Participants came from throughout the world to learn about the new, rapidly developing field of nuclear reactor technology. Today, graduates are the leaders of national programs in many countries involving the peaceful applications of nuclear technology.

In 1976, Argonne was designated by the Department of State as host institution for U.S. participation in the new Nuclear Power Training Program of the International Atomic Energy Agency (IAEA). Under this program the Laboratory develops, organizes, and conducts training courses covering a full range of topics in the peaceful applications of nuclear technology. Subject areas include nuclear power, power and research reactor safety, decontamination and decommissioning, energy planning, nuclear electronics, and environmental monitoring. Approximately 3,000 professionals from over 100 countries, representing essentially all developing member states of the IAEA, have received intensive training through these courses.

Argonne also provides technical and management support to the Department of State and directly to the IAEA. One major activity is evaluation of "technical cooperation projects" proposed for funding by the United States, along with monitoring and facilitation of the implementation of such projects once funded. The Laboratory also developed and now maintains — by means of an electronic database — an "institutional memory" of U.S. support for technical cooperation projects, as well as extensive project files, IAEA reports, and evaluation studies. The Laboratory also supports the Department of State and the IAEA in their initiatives to improve the agency's Technical Cooperation program. Argonne regularly reviews and analyzes the program's management and achievements. The Laboratory also develops recommendations on matters of policy or practice related to U.S. support for the program.

4. Department of Health and Human Services

The National Institutes of Health (NIH) support a broad range of fundamental studies at Argonne. These investigations often apply techniques developed in DOE-supported programs to studies in biophysics, carcinogenesis, mutagenesis, and physiology.

The majority of these studies emphasize structure-function relationships or mechanisms underlying biological responses. Two projects are investigating abnormal regulation of expression of the proliferating cell nuclear antigen gene in wasted mice. The objective is to determine whether a deletional mutation in the promoter region of the gene is responsible for the "wst" mutation and the "wasted" phenotype of mice with motor neuron degeneration, radiation sensitivity, and immunodeficiency. These studies also involve the identification and characterization of genes induced in cultured cells following exposure to DNA-damaging agents.

Biophysical studies are addressing the properties of human antibody light chains that lead to pathologic deposition in myeloma. Investigations of *in vitro* aggregation of light chains consider their structure and pathologic characteristics. One project is investigating the mechanisms by which cadmium causes bone loss and is relating the findings to human exposure.

NIH is supporting a major new effort in structural genomics at Argonne. The field of structural genomics aims ultimately to determine the three-dimensional structures of all proteins. The Laboratory's effort for NIH, in partnership with the DOE-funded Structural Biology Center at Argonne's Advanced Photon Source (APS), will create the Midwest Center for Structural Genomics (MCSG). NIH will provide approximately $5 million annually through FY 2005 to establish high-throughput methods for determining the three-dimensional structures of biological macromolecules. Argonne is lead institution in the MCSG consortium, which also includes six universities. As recently as 1990, solving a single protein crystal structure could take one or more scientists several years. At Argonne, improved data collection and analysis techniques now allow the structure of a protein to be solved in as little as six hours. In 1999, more new protein structures were determined at the Structural Biology Center than at any other synchrotron beamline in the world. Using X-rays from the APS, the Center collects very-high-quality data thousands of times faster than was possible even a few years ago. By developing (1) robotic methods to carry out tedious experimental procedures and (2) advanced computational methods for analysis of data and structure determination, Argonne has achieved huge leaps in productivity. NIH support of the MCSG will enable further significant improvements in productivity.

NIH is also partnering with Argonne to construct and operate a Protein Structure Center at the APS. This effort will parallel and cooperate with the MCSG. Utilizing two undulators and a bending magnet, it will develop three X-ray beamlines optimized for macromolecular crystallography. Office and laboratory space for staff and users will be developed in a new office-laboratory module to be constructed at the APS. The beamlines will include high-throughput robotic sample delivery, high-speed data collection with on-line analysis, and remote access through interactive computer networks. Construction, beginning in FY 2001, is planned in two sequential phases that will allow data collection to begin at the first beamline during construction of the other two beamlines.

Argonne provides technical support to the U.S. Public Health Service, Division of Federal Occupational Health, in the development and implementation of an environmental health and safety assessment program for the U.S. Social Security Administration. The principal objective is to develop an overall program framework, plans and protocols, and facility assessments at randomly selected facilities in ten regions. Information gathered during pilot assessments in the first two regions will be used to guide subsequent work.

5. Department of Transportation

For the Research and Special Projects Administration, Argonne continues to model the effects of accidents resulting from transportation of chemicals on the nation's highways and railways. These models were used in developing a *North American Emergency Response Guidebook* for the year 2000. The models will address (1) protective action distances from accidents involving spills on highways and rails and (2) chemical spills into bodies of water from highway and rail accidents. In support of regulation development, the Laboratory is involved in a national assessment of risks (especially risks through inhalation) associated with transporting toxic chemicals.

6. Department of Agriculture

As part of an ongoing program for the Commodity Credit Corporation of the U.S. Department of Agriculture (CCC/USDA), Argonne supports remediation of sites having contaminated groundwater and soil by integrating field sampling, groundwater modeling, and engineering cost analyses. The Laboratory is also evaluating sources of contamination in the soil and methods of treating groundwater. New cone penetrometer technologies are being assessed for potential contributions to the CCC/USDA's remediation requirements.

7. National Science Foundation

Through a subcontract to the University of Tennessee, Argonne is participating in a proposal to the National Science Foundation (NSF) to develop a full proposal to construct a long-wavelength target station (LWTS) for the Spallation Neutron Source being built at Oak Ridge National Laboratory. See Section S1.D.3 for more information.

Argonne is a partner in the National Computational Science Alliance, funded by the NSF Partnerships for Advanced Computational Infrastructure program (see the Web location www.ncsa.edu/). Researchers are developing software for collaborative problem solving, distributed computing technology and advanced visualization tools, and parallel input-output technology.

Argonne participates in an NSF-sponsored program in geoenvironmental engineering with Northwestern University, the University of Michigan, and the University of Wisconsin. The Laboratory contributes environmental risk assessment research and experience in applications.

The Laboratory participates in a joint NSF-NOAA (National Oceanic and Atmospheric Administration) project examining the importance for coastal processes of episodic events in the Great Lakes. Argonne's roles in the five-year program include making *in situ* measurements of physical conditions within one meter of the lake bottom and determining very low concentrations of radioactive tracers in lake sediments.

8. National Aeronautics and Space Administration

For the National Aeronautics and Space Administration (NASA), Argonne is developing test beds to study applications on distributed computational grids.

In another project for NASA, Argonne is developing a model that uses limited surface meteorological observations in the Walnut River Watershed in Kansas, together with optical reflectance data obtained from satellites, to infer surface soil moisture conditions and to study the effects on evapotranspiration rates of horizontal variations in soil moisture availability. The model will be able to evaluate evapotranspiration over large areas and long time periods and thus will substantially reduce uncertainties in the hydrologic balance for various watersheds in the Midwest and the Great Plains.

9. Department of Commerce

Argonne works with two organizations within the Department of Commerce: NOAA and the National Institute of Standards and Technology (NIST).

The Laboratory is collaborating with NOAA's Great Lakes Environmental Research Laboratory and Ohio State University to develop algorithms for interpreting multispectral satellite observations of the Great Lakes. This work involves field studies of the Great Lakes' optical properties and the development of specialized radiative transfer models appropriate for the optically complex waters typical of the Great Lakes.

The NIST Advanced Technology Program (ATP) requires participating private companies to match NIST funding. The private sector can then choose to subcontract to the national laboratories in the pursuit of new technology. See Section S1.D.2 for further discussion.

10. Veterans' Affairs

As an extension of an earlier project, Argonne is working with the Veterans' Health Administration, Department of Veterans' Affairs, to develop advanced, intelligent information technology tools to handle requests made under the Freedom of Information Act. (This work is being conducted in conjunction with work for the Secretary of the Air Force, Office of the Inspector General.)

D. Nonfederal Organizations

1. Electric Power Research Institute

Argonne conducts research for the Electric Power Research Institute (EPRI) on topics related to the risk of a severe accident at a nuclear power plant. Major experiments were conducted to measure the release of fission products in aerosol form when concrete is attacked by molten core materials. Resulting data have been analyzed, and new work is under discussion. Argonne's current work on the Melt Attack and Coolability Experiment program is particularly important. This work investigates the ability of water to quench and cool a pool of molten core debris without formation of a continuous insulating crust, thereby terminating an accident and preventing basemat penetration. The work has attracted worldwide attention because of its importance to strategies for managing accidents at existing plants and its great relevance to design decisions for future light-water reactors. These experiments are sponsored by the 15-nation Advanced Containment Experiments program headed by EPRI, which pursues realistic understanding of the consequences of an accident involving core melting.

Complementary Argonne programs have directly measured the thermophysical properties of core debris and concrete and have addressed the ability of melted core materials to spread to a readily coolable configuration on concrete. Argonne programs for EPRI generally have the objective of resolving key safety issues through a combination of analysis and experiments. Recently developed computer codes (MELTSPREAD and CORQUENCH), based on data from these experimental programs, are being used to analyze accident phenomena.

2. Private Firms

Argonne conducts research for a number of private firms, making use of its unique facilities and technical resources. Current work for private firms includes the following:

- Center for Land Renewal: Development of an industrial triage system for use in evaluating brownfield sites.
- Furness-Newburge, Inc.: Sonic research to locate and remediate damage in underground natural gas storage wells.
- Genencor International: Development of continuous biocatalytic systems for producing chemicals from renewable resources. (Funding is from the NIST ATP.)
- General Atomics: “Smart sensor” technology to monitor conditions in the compartments of ships. (Funding is from the Naval Research Laboratory.)
- General Motors Electro-Motive Division: Improvement of the efficiency and emissions characteristics of diesel engines.
- Guidant Corporation: Medical batteries.
- Houston Advanced Research Center: Technical support on methods of destroying illicit substances seized by law enforcement agencies, including the development and testing of transportable medical waste incinerators, an off-gas system, and a shredder feeder system.
- IBM: Development of a computational tool for visualizing the results of very large programs.
- Microsoft: For Windows NT, development of MPICH, a portable, high-performance implementation of the message-passing interface.
- National Center for Manufacturing Sciences: Develop advanced technologies for locating and quantifying small leaks, for example in process piping.
- NRG Energy, Inc.: Environmental impact analysis for a 500-kV transmission line.
- Salyp: Technology for recycling materials from auto shredder residues; technical support for implementation and commercialization through a demonstration facility targeted for start-up in 2001.
- Science Applications International Corporation: Technical support for four seismic profiles that cross the mapped or inferred surface trace of the Jacksonville Fault.
- Solar Turbines, Inc.: Nondestructive evaluation for ceramic components of stationary gas turbines.
- Superior Graphite Company: Development of nonintrusive controls for an electroconsolidation process intended to replace hot isostatic pressing in the forming of mechanical components. (Funding is from the NIST ATP.)
- TRW, Inc.: Research, design, and field application of a performance measurement system for the chemical stockpile emergency preparedness program.

In addition to the activities administered under Argonne’s WFO program, as discussed in this Supplement 1, the Laboratory also performs work with its partners in cooperative research and development agreements (CRADAs). These activities are discussed in Supplement 2.

Argonne's work for private firms often grows out of industry-laboratory collaborative projects. An example is the Argonne Laser Applications Laboratory, which conducts R&D to support the use of high-power lasers in materials processing for manufacturing. Industrial partners include automotive manufacturers and suppliers and also several small businesses. Current work focuses on applying laser ablation in decontamination and decommissioning (D&D) activities funded by DOE's Environmental Management Science Program. The Laser Applications Laboratory also provides technical service to several private companies. Processing techniques available include high-power beam shaping and delivery, fiber optics, surface modification, and welding. In addition, work by the Laser Applications Laboratory supports Argonne's major facilities and programs, such as the Advanced Photon Source, the Intense Pulsed Neutron Source, the fusion power program, and D&D of reactor systems.

3. Universities

Current Argonne work for universities includes the following:

- California Institute of Technology: Scalable input/output for the Accelerated Strategic Computing Initiative.
- Indiana University: High-performance network connection for research and education.
- Northwestern University: Metacomputing environments for optimization; participation in the Optimization Technology Center.
- University Corporation for Atmospheric Research: High-performance computing and software engineering for development of next-generation mesoscale models.
- University of Illinois at Urbana-Champaign: Partnership for Advanced Computational Infrastructure program.
- University of Wisconsin at Milwaukee: Episodic events on the coasts of the Great Lakes.

Through a subcontract to the University of Tennessee, Argonne is participating in a proposal to the National Science Foundation (NSF) to develop a full proposal to construct a long-wavelength target station (LWTS) for the Spallation Neutron Source being built at Oak Ridge National Laboratory. Submitted in November 1999, the proposal requests a total of $4.5 million over three years. The first year of work, scheduled to start in mid FY 2000, was funded at $1.44 million. This effort will be devoted to developing the conceptual design report (CDR) for the LWTS. Approximately $400,000 will support development of the CDR for the instruments, with a roughly equal amount funding the CDR for the target-moderator assembly. Both of these studies will be directed by scientists at Argonne's Intense Pulsed Neutron Source. The full CDR, to be submitted early in FY 2001, will request construction funds of $200-300 million, starting in FY 2003; construction will involve several Argonne divisions. The second and third year of work will be devoted to R&D associated with the LWTS. Argonne's lead role in developing the LWTS CDR reflects many years of experience and a worldwide reputation for designing instruments and target systems for pulsed neutron sources.

For interdisciplinary research in computational science, Argonne and the University of Chicago have established the Computation Institute, which is distinguished from similar centers by emphasis on challenging problems in the arts and humanities, as well as in the sciences. The initial focus is on four themes: computational biology, fluid dynamics, computational structures, and societal and human impacts. The Institute facilitates Argonne's access to students and postdoctoral researchers and gives the University of Chicago access to unique computational resources. The new Institute also is expected to facilitate contributions by Argonne to research supported by agencies other than DOE.

Argonne is also collaborating with researchers at the University of Chicago Center on Astrophysical Thermonuclear Flashes (see the Web location www.asci.uchicago.edu/). This interdisciplinary center is using the latest techniques in computational science, computer science, and validation to solve the long-standing problem of thermonuclear flashes on the surfaces of compact stars.

4. State Governments

For the state of Illinois, Department of Commerce and Community Affairs, Argonne is working on two major projects. In the first, the Laboratory is performing research aimed at developing an advanced, high-capacity computer network linking major research centers and universities in the state. The network will enable detailed power and engineering feasibility studies, as well as development of advanced interfaces for geographically distributed applications. In the other project, Argonne is constructing the Commercial Beamline at the Advanced Photon Source, which will serve Illinois companies performing X-ray experiments involving spectroscopy, diffraction, scattering, and crystallography. The state will also contribute to the operating costs for the new beamline.

To protect nearby residents in the unlikely event of an accidental release of obsolete chemical weapons agents stockpiled at the U.S. Army's Anniston Chemical Facility, the Alabama Emergency Management Agency is sponsoring research to support improvements in emergency planning. Working with the University of Alabama at Birmingham, Argonne is contributing to these efforts by carrying out one of the most intensive searches ever undertaken for individuals having disabilities that might prevent them from helping themselves by evacuating or taking shelter. The work entails integration of an array of survey research techniques. In addition, the Laboratory is developing novel geocoding methodologies and database management procedures in order to identify and map major employers, care facilities, and other relevant institutions in a six-county area.

5. International Organizations and Foreign Countries

Argonne is working with the World Bank and countries borrowing from the Bank on energy and environmental analyses addressing issues such as planning least-cost expansions for electrical generating systems, estimating marginal costs of electricity production, simulating the operation of mixed hydrothermal systems, projecting overall energy supply and demand, analyzing current and future environmental effects of energy production and consumption, estimating the potential for future pollution abatement projects and their costs, and estimating the costs and effects of greenhouse gas mitigation options. Argonne typically conducts these studies in close cooperation with experts in the borrowing countries, who are often trained to use the analytical techniques themselves.

In nuclear reactor technology, Argonne's unique capability to perform severe-accident experiments with real reactor materials is utilized by international sponsors. The Laboratory currently works with Atomic Energy of Canada, Ltd., on an experiment to explore molten fuel-fluid interaction for the CANDU reactor. In the area of structural and seismic engineering, Argonne collaborates with the Korea Atomic Energy Research Institute on testing of material for seismic-isolation bearings.

Argonne collaborates with the Korean Environmental Management Corporation on environmental restoration issues. The Laboratory will transfer restoration methodologies and technologies and will help adapt them to meet Korea's needs.

The Laboratory is collaborating with Egypt's Cairo University to establish there a state-of-the-art Center for Environmental Hazard Mitigation. This five-year project will address Egyptian environmental problems such as urban encroachment onto the fertile lands of the Nile Delta, sea shoreline erosion, seismic hazards, and air and water pollution. Also being evaluated are the origin of seismic activity around the Aswan High Dam, the environmental impacts of the New Valley Project, and the sources of groundwater in the newly reclaimed lands in Egypt's western and eastern deserts.

Argonne works directly with many foreign countries to provide energy and environmental analyses, along with training in the use of supporting computer models including Argonne's ENergy and Power Evaluation Program (ENPEP) and the Generation and Transmission Maximizer (GTMax).

In one case the Laboratory is working with the Turkish Electricity Generation-Transmission Company (TEAS) to evaluate development of the Turkish energy system and its environmental impacts. The country's Ministry of Energy and Natural Resources is collaborating with TEAS on this project, which is funded by the World Bank. Included in the analysis is the entire Turkish energy supply system — coal, oil, natural gas, electric power, and renewable resources — as well as all end user sectors.

In another case, Argonne assists the Hungarian Power Companies, Ltd., in evaluating specific proposals from independent power producers for new electric power generating capacity. The Laboratory develops and tests an evaluation methodology by using the ENPEP model; provides technical assistance during actual evaluations; and trains utility staff to use the GTMax model to plan for maximum system profits, optimized system operation, and the optimal mix of spot market transactions and firm contract purchases within a European energy market that is soon to be liberalized.

In a third project, sponsored by the World Bank and the United Nations Development Program, the Laboratory is collaborating with Uruguay's Presidential Office of Planning and Budget to analyze Uruguay's future energy supply options and the potential for greenhouse gas mitigation under the U.N. Framework Convention on Climate Change. This analysis takes into account domestic refinery modifications, rehabilitation of thermal generating units, potential natural gas imports from Argentina, and electricity exchanges with Argentina and Brazil. The environmental analysis includes an emissions inventory of greenhouse gases and criteria pollutants, emissions projections under various energy development scenarios, and identification of options for greenhouse gas mitigation.

In a fourth project, Argonne is working with the Jamaican Ministry of Mining and Energy and using the ENPEP system to study energy and electricity options for that island nation.

Argonne is the operating agent for the program of the International Energy Agency titled "Implementing Agreement for a Co-Operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector." The Laboratory's main role is to keep member countries informed about the status of superconductivity research and its progress toward application. Argonne is also involved in a project to evaluate hardware feasibility. The implementing agreement is funded by organizations in 16 countries, including the United States.

Other current work for foreign countries includes the following:

- Oxford Instruments (United Kingdom): Large-area charge-coupled-device detector.
- Power Reactor and Nuclear Fuel Development Corp. (United Kingdom): The safety of treating the sodium systems of fast reactors.

Supplement 2: Technology Transfer

In pursuit of its R&D and technology transfer missions, Argonne interacts extensively with researchers — and their organizations — who are interested in using the Laboratory's technologies. Such interactions, in many cases through R&D partnerships, enhance the Laboratory's programs and provide a means by which the discoveries, developments, and methodologies created by Argonne can be commercialized, to the benefit of U.S. economic productivity and society more broadly.

Argonne's Industrial Technology Development Division (ITD) is the Laboratory's mechanism for ensuring effective technology transfer. ITD manages collaborative agreements, including cooperative research and development agreements (CRADAs) and High-Temperature Superconductivity Technology Center agreements (HTSCAs); protects and licenses intellectual property developed by the Laboratory; conducts outreach activities; and serves as a point of contact for inquiries concerning Argonne technology.

Argonne employs collaborative partnerships to maximize the commercial applications resulting from its R&D and the resulting benefits to the nation. Managers of relevant Laboratory programs meet weekly as the Partnerships Committee to explore opportunities for technology transfer to industry and for R&D programs that will lead to such transfers. In addition, eight subcommittees meet regularly to coordinate opportunities in focus areas based on the Laboratory's research: (1) transportation technology, (2) materials development, (3) process industries technology, (4) utilities technology, (5) carbon management technology, (6) biotechnology, (7) environmental stewardship, and (8) urban technology.

Argonne plans to continue its aggressive pursuit of technology transfer. Table S2.1 summarizes the funding and staffing associated with these plans.

A. Research and Development Agreements

Argonne's collaborative research is generally conducted under CRADAs and HTSCAs. Other types of agreements employed include personnel exchanges, contracts for reimbursable work for sponsors other than DOE ("work for others" or WFO), and technical services agreements.

1. Cooperative Research and Development Agreements

CRADAs have proved valuable to both industry and the Laboratory. Argonne's industrial partners have created new products and processes, new markets, and new jobs. The Laboratory's scientists have access to industrial expertise and facilities that are not available on-site. Cooperative research also has generated a substantial number of Argonne's inventions, several as joint industry-Laboratory inventions.

Under a typical CRADA, both the partnering organization and Argonne contribute to the cost of the research. Proprietary information is kept confidential, and results from the work can be protected from disclosure for up to five years. A company may obtain rights to intellectual property developed by Argonne under the agreement.

Argonne promotes fairness of access to CRADA opportunities at the Laboratory by publicizing its capabilities and interests through wide-ranging channels such as technical conferences, trade shows, direct mailings, announcements in *Commerce Business Daily*, articles in trade journals and other publications, and an extensive web site.

In FY 1999 the Laboratory's total CRADA actions increased by 31% over FY 1998, from 26 to 34. The total of 34 included 21 new CRADAs, a 50% increase over FY 1998. The total contract

Table S2.1 Federal Technology Transfer Funding and Effort[a]

	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Funding ($1,000)							
Industrial Technology Development Division[b]	2,039	2,100	2,200	2,300	2,400	2,500	2,600
SC-LTR[c]	1,300	1,800	2,400	3,300	4,000	4,700	5,400
High-Temperature Superconductivity Technology Center[d]	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Other cost-shared contracts	1,500	1,500	2,000	2,000	2,000	2,000	2,000
CRADAs (other than SC-LTR funding)	11,000	12,000	13,000	14,000	15,000	16,000	17,000
Total Federal Cooperative Research Funding	17,800	19,300	21,400	23,300	25,000	26,700	28,400
Staffing (FTE)							
Industrial Technology Development Division Activity	16	17	18	18	18	18	18

[a]Includes only activities of Argonne's Industrial Technology Development Division.

[b]Includes funding for the services of outside patent attorneys at $230,000 annually, escalated for inflation.

[c]The DOE Office of Science, Laboratory Technology Research Program.

[d]The High-Temperature Superconductivity Technology Center is an integrated program devoted to rapid development of commercial applications for high-temperature superconductivity materials and components. In FY 2000 approximately $1.35 million will be used to support partnerships; the remaining funding will be used to develop base technology that supports the partnerships.

value for these actions declined from $64.2 million in FY 1998 to $24.1 million in FY 1999. DOE funding increased from $5.1 million to $8.1 million. Industry funding to the Laboratory fell precipitously from $19.0 million to $1.0 million. (The FY 1998 total included a very large $15 million funds-in contract with Motorola, Inc., and Packard Instrument Company.)

In FY 2000 DOE funding is expected to increase slightly. Industry funding to the Laboratory should increase substantially, to at least $2 million.

The remainder of this section is devoted to highlighting some of the Laboratory's significant industrial partnerships.

Argonne continues to expand the range of applications for Ceramicrete, its novel advanced-ceramic material. ITD led a cross-functional team (which included the legal, procurement, and accounting departments and the Energy Technology Division) in developing a new technology transfer mechanism that allows Argonne to sell the Ceramicrete binder to potential research partners. The Laboratory has sold more than half a ton of Ceramicrete binder in research-quantity samples to nearly 40 customers who have shared their experience in working with the binder. This information from commercial applications is helping Argonne researchers further broaden their understanding of the technology. Argonne originally developed Ceramicrete to stabilize DOE waste streams.

ITD supported transfer of the Ceramicrete technology by focusing on 5,000 customer leads. Argonne licensed Ceramicrete to one company in FY 1997, another in FY 1998, and two in

FY 1999. The Laboratory is currently negotiating five additional licenses. Three of the four established licensees are small businesses, two minority owned. Seven of the nine licenses established or under negotiation are supported by either a CRADA or a WFO agreement. The Laboratory expects to receive a minimum of nearly $3 million in royalties from these nine licenses between FY 2000 and FY 2008.

Under a three-year CRADA with Eagle Picher Industries begun in FY 1999, Argonne's Ceramicrete may soon find use in castable shielding for nuclear reactors, in containers for transporting and storing spent nuclear fuel, in biological shielding, and in pumpable emergency shielding material for nuclear disasters. Argonne and Eagle Picher are working jointly to improve Ceramicrete's radiation stability — that is, its ability to absorb alpha, beta, and gamma rays and neutrons — while maintaining its mechanical and thermomechanical properties. The goal is a versatile shielding material having greater flexibility for containing and storing a wide range of wastes with minimal environmental impact. During the final two years of this CRADA, the technology will be scaled up and commercialized. Eagle Picher Industries was the fourth company to license the Ceramicrete portfolio.

Under a CRADA with Motorola, Inc., joint research is continuing toward commercialization of advanced biological microchips ("biochips"). Motorola has produced test quantities of the biochips and is expected to make them commercially available in the near future. This technology is expected to make the process of decoding genes, for humans or other living things, a thousand times faster than is currently possible. A former partner in the CRADA, Packard Instrument Company, now has two related instruments on the market: an analyzer and a loader.

Argonne has several CRADAs with the oil-refining industry. These agreements directly support DOE's Refinery of the Future initiative, which promotes energy conservation and minimization of environmental impacts. One of the CRADAs — with UOP, Inc., and Chevron Research and Technology Company — focuses on developing a multiphase-flow computational-fluid-dynamics (CFD) model of fluid catalytic crackers that can be used to optimize their design and operating parameters in order to increase yields of lighter, more valuable products. More generally, the resulting major advances in multiphase CFD modeling will benefit key processes in other industries such as glass, aluminum, and forest products.

In the area of biobased chemicals, two CRADAs have resulted from Argonne's development of a bioprocess that uses advanced membrane technology to produce lactate esters from corn. A CRADA with the former NTEC/Versol (now Vertec Solvents) seeks to develop lactate ester technology further in order to produce ethyl lactate as a biodegradable "green" solvent approved by the Food and Drug Administration. Vertec Solvents licensed Argonne's technology in specified fields of use and, under a marketing agreement with a major agriprocessor, is seeking to develop and expand worldwide markets for ethyl lactate solvents. Argonne has received several awards in biobased chemicals, including the Presidential Green Chemistry Challenge Award, a Discover Award for technology innovation, and the Ernest W. Thiele Award from the American Institute of Chemical Engineers. The Federal Laboratory Consortium recognized the technology's developers with an award for excellence in technology transfer. The technology also is one of three finalists (among 1,000 entries) for designation as "project of the year" by DOE's Office of Industrial Technologies.

In a second CRADA in the area of biobased chemicals, work on two-stage electrodialysis spawned a new company, NTEC EDSep, which extended the lactate ester membrane technology to other industrial applications. A project extending this CRADA is focusing on membrane-related applications in order to develop an electro-deionization (EDI) process. A field demonstration is planned for 2001 at the site of an agriprocessor. This technology could greatly reduce the cost, energy consumption, and chemical waste generation associated with ion exchange technology by allowing in-place regeneration of the ion exchange materials with minimal loss of product. Argonne's EDI technology employs a novel design suitable for industrial process streams, unlike EDI applications developed previously for high-purity water purification.

A related CRADA with Unitel (a small Illinois company) and UOP, Inc., focuses on developing membranes suitable for low-cost production of hydrogen peroxide. Currently, hydrogen peroxide production uses large-scale equipment under somewhat hazardous conditions. Smaller, modular facilities and less toxic chemical routes are desirable. Further development of advanced membranes at Argonne holds great promise for application to hydrogen peroxide processing, and it will facilitate application of this unique technology to other industrial processes.

In FY 2000 Argonne executed a CRADA with Noranda Magnesium to develop nonconsumable anodes that will reduce chlorohydrocarbon emissions from magnesium production and will enable improved cell designs that reduce production costs and energy consumption.

Argonne has several projects with the transportation industry that also focus on reducing energy use and minimizing pollution. Contracts with the U.S. Council for Automotive Research (USCAR, a partnership among DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation) focus on pollution control and the development of advanced batteries for electric vehicles. With ADAPCO (Analysis and Design Application Company, Ltd.), USCAR, and Oak Ridge National Laboratory, Argonne is studying the way heat loads are handled under the hoods of automobiles. The research focuses on developing improved computer models for vital system components that affect heat transfer (such as fans and heat exchangers) and on the use of advanced numerical techniques. Under the USCAR umbrella, a continuing CRADA with 3M and Hydro-Quebec aims to develop lithium-polymer batteries for electric vehicles. A CRADA with the Association of American Railroads (the trade association for the North American railroad industry) and the General Motors Electro-Motive Division focuses on improving combustion and pollution control technology. This cooperative research has resulted in a breakthrough oxygen enrichment technology that simultaneously reduces both particulates and nitrogen oxides and increases diesel engine power. The technology relies on an advanced polymer membrane developed by Argonne in cooperation with Compact Membrane Systems, Inc., under a separate CRADA. Another Argonne CRADA, with Caterpillar, Inc., is focusing on optimizing the performance of diesel engines while minimizing emission of particulates and other pollutants.

The Initiatives for Proliferation Prevention program and the U.S. Industry Coalition facilitate cost-shared commercialization projects that help countries of the former Soviet Union divert technical staff at their weapons institutes to nonmilitary activities. Currently, cooperative research of this kind is being pursued with several companies: SI Diamond Technology (thin-film cathodes for field emission displays), Clean Air Engineering (millimeter-wave sweeper and gas analyzer), United Technologies (reduced emissions through fuel reforming in gas turbines), Soiltech Environmental (soil washing with a pulsed column), and Eagle Picher (as discussed previously in this section).

2. High-Temperature Superconductivity Technology Center Agreements

Argonne's High-Temperature Superconductivity Technology Center is an integrated program devoted to rapid development of commercial applications for high-temperature superconductivity materials and components. Under a typical HTSCA, both the partnering organization and Argonne contribute to the cost of the research. Proprietary information is kept confidential, and results from the work can be protected from disclosure for up to two years. Under an HTSCA, a company may obtain the rights to intellectual property developed by Argonne.

In FY 2000 approximately $1.35 million of DOE funds will be used for partnerships. Remaining funding will be used to develop base technology to support the partnerships.

Under HTSCAs, the Laboratory has developed several enabling technologies that are now being used by industry, such as vacuum calcination for powder synthesis, microstructural texturing, silver composite processing, melt processing, and buffer-layered architecturing. In addition, the Laboratory has developed five product-oriented technologies: a fault current limiter, current leads, magnetically levitated bearings, flywheels, and superconducting wires.

Argonne's strength in the development of advanced materials has been coupled very effectively with industrial expertise and facilities to achieve dramatic advances toward practical superconductors. Cooperative research with the Laboratory in this leading-edge technology area has been particularly valuable to small companies that were formed to pursue commercial applications of high-temperature superconductivity. One such company, Superconductive Components, Inc. (SCI), now manufactures four varieties of high-temperature superconducting powders by using an Argonne process. Compared with alternatives, this method reduces processing time by 60% and yields cost savings estimated at 40% (amounting to about $180 per pound of material produced). SCI also globally markets high-temperature superconducting levitators, produced under license to Argonne, for use in applications such as flywheel energy storage based on superconducting magnetic bearings.

With the Laboratory's assistance, American Superconductor Corporation (ASC) produced short, rolled, silver-sheathed bismuth-2223 conductors with a critical current density of 70 kiloamperes per square centimeter — a world record. In FY 1999, ASC manufactured more than 200 kilometers of bismuth-2223 tapes, which were used in ASC projects with other industrial partners. ASC prototype products include transmission cable, transformers, and motors.

Intermagnetics General Corporation (IGC) also manufactured bismuth-2223 tapes in FY 1999, with production totaling approximately 100 kilometers. Prototype tapes are being used in transmission cables, transformers, and current limiters. IGC built the world's largest high-temperature superconducting coils — each more than 1 meter in diameter and 75 centimeters in height and each requiring about 15 kilometers of high-temperature superconducting tape.

3. Work for Others

Argonne conducts work for sponsors other than DOE, including industrial firms, universities, and state and local governments. This "work for others" is discussed in Supplement 1.

4. Personnel Exchanges

Argonne exchanges scientific staff with industrial firms through a variety of mechanisms, including CRADAs and guest agreements. Appointments generally range from three months to one year but may be as brief as a few days.

Personnel exchanges most often involve a scientist or engineer from industry working at the Argonne site and using the Laboratory's expertise and facilities to pursue technical challenges of mutual interest. These exchanges give Argonne researchers the benefit of industrial perspective, and mutual familiarity and understanding often lead to subsequent collaborations.

5. Technical Services Agreements

Argonne provides limited assistance to companies to help them solve technical problems where the required expertise is not commercially available. In some cases, a wider-ranging agreement that involves the Laboratory in collaborative or reimbursable R&D has resulted from technical services.

Argonne has two mechanisms for providing technical assistance to companies: (1) reimbursable technical service contracts and (2) the Technical Services Program. Neither may include R&D. Under reimbursable technical service contracts, companies pay the full cost of the Laboratory's effort. In FY 1999 the Laboratory assisted 57 companies in this way. Under the second mechanism, the Technical Services Program, Laboratory researchers use their unique expertise to provide limited scientific assistance that is not available commercially, typically to help small businesses solve immediate problems. This program is funded by the Laboratory Technology Research Program of DOE's Office of Science. In FY 1999 the Laboratory assisted seven companies in this way.

B. Patenting and Licensing

Pursuant to federal law and the *Prime Contract* between the University of Chicago and DOE for operation of Argonne, in FY 1992 the University of Chicago began using federal funds to patent inventions and to register copyrights for software. The Laboratory manages and licenses intellectual property created at Argonne and expects these activities to continue.

Argonne protects its inventions and software to prepare for potential licensing and to establish technical leadership in areas related to its mission. Stakeholders throughout the Laboratory participate in decision making concerning intellectual property.

For each invention and copyrightable software reported by a Laboratory inventor or author, ITD convenes an *ad hoc* intellectual property decision group that is attended by the inventor, management of the inventor's division, the Laboratory's chief patent counsel, and ITD managers. Normally the group meets within 30 days of receipt of a report by the chief patent counsel; topics discussed are the patentability and scope of the innovation, the Laboratory's obligations to grant options or licenses to contractual partners, and appropriate approaches to follow-on activities such as development, protection, and licensing. Meeting minutes are distributed to attendees and their respective managements.

For inventions deemed to have the greatest commercial potential — on the basis of their uniqueness, value, and timeliness — ITD develops commercial assessments aimed at transferring the Argonne technologies to industrial companies. The assessments focus on commercial potential by examining such factors as technical value compared to current alternatives, cost of implementation, industry trends, and overall need for the technology. The Laboratory cooperates with industrial participants to find the route to commercialization that promises the shortest delay or the greatest ultimate impact. Argonne technologies being transferred in this way in 2000 include nanocrystalline diamond films, Ceramicrete chemically bonded ceramic, and aqueous biphasic extraction/organoclay technologies.

Argonne has developed and implemented detailed procedures for electing inventions; prosecuting patents; registering copyrights; and tracking costs, licensing arrangements, and royalty collection and distribution. Relational databases are used to coordinate intellectual property management with collaborative agreements and licensing arrangements.

Table S2.2 describes the amounts and uses of income from the licensing of Argonne inventions. The royalties received to date stem from two sources: (1) up-front payments for licenses, options, and assignments and (2) running royalties from the sale of products.

Table S2.2 Licensing Income and Use

	FY99	FY00	FY01	FY02	FY03
Licenses[a]					
Number of New Licenses					
Argonne	15	20	25	30	35
ARCH	1	2	2	2	2
License Income ($1,000)					
Total	1,003.9	1,400	1,900	2,250	2,700
Argonne	823.1	1,200	1,675	2,000	2,625
ARCH	180.8	200	225	250	275
Use of Income ($1,000)					
ARCH Administration	181.3	200	225	250	275
Awards and Inventor Payments	244.8	350[b]	475[b]	565[b]	675[b]
Total Available for Laboratory R&D	759.1	850	1,200	1,435	1,950

[a]Includes income contractually shared with other organizations.
[b]Equals 25% of Argonne and ARCH license income.

The number of income-producing license and option agreements newly executed by the Laboratory for specific, identified intellectual property developed under federal funding has increased steadily each year, reaching 18 in FY 1999. In addition, each CRADA includes an option for industrial partners to obtain a license in Laboratory inventions made by employees during work under CRADA funding. License initiation fees and running royalties associated with executed licenses range from minimal amounts received under low-fee licenses up to payments potentially reaching millions of dollars. In FY 1999 the Laboratory had 68 active license agreements (including the 18 new agreements).

Argonne has developed a comprehensive set of policies and procedures for identifying commercially valuable data, for obtaining DOE permissions for protection, and for registering copyrights in software codes and documentation. Some copyrighted software codes and documentation are licensed for a fee to commercial and educational organizations; others are distributed broadly under free licenses. The Laboratory also registers trademarks associated with software and some invention portfolios, for the purpose of distinguishing the Laboratory's intellectual property when it is reported in scientific and trade publications and in technology transfer materials.

Royalty shares resulting from the licensing of Argonne technology are first disbursed to inventors and authors. The remainder of the royalties are returned to the Laboratory divisions from which the licensed technology originated, to be used for R&D within policies set by the Laboratory in accordance with the *Prime Contract*.

The remainder of this section is devoted to highlighting recent licensing actions by the Laboratory.

MSET is an early-warning expert system that substantially outperforms all currently available methods for monitoring the performance of a plant's sensors, equipment, and processes. By detecting the smallest developing faults at the earliest possible time, this extremely sensitive system provides an alert. MSET distinguishes between sensor failures and disturbances in operating conditions or equipment, and, if a sensor fails, it can provide a high-precision replacement signal for the failed sensor so that operations can continue without interruption until the sensor is replaced at its scheduled maintenance time. The Laboratory's intellectual property portfolio related to MSET contains more than 20 patents and copyrighted software programs. MSET has been licensed by Argonne to several nuclear power utilities and provided, under government license, to the Tennessee Valley Authority. The company SmartSignal, formed to commercialize MSET software, has a product on the market and is continuing to develop its licensed technology.

In FY 1999 Argonne licensed its technology for the recycling of materials from automobile shredder residues to Salyp N.V. of Belgium. Under a reimbursable technical services agreement, Laboratory staff are providing technical support to Salyp for the implementation and commercialization of the licensed technology. Salyp is building a demonstration facility that is targeted for start-up in early 2001. Under the terms of the technical services agreement, Argonne is assisting Salyp in developing full-scale designs for the required equipment and, on Salyp's behalf, is coordinating contacts with selected U.S. equipment manufacturers. The equipment includes (1) a two-stage rotary trommel for bulk separation of shredder residue and (2) equipment designed and patented by Argonne for cleaning and drying polyurethane foam. Argonne also will provide assistance during construction and start-up of Salyp's demonstration plant and will provide ongoing assistance during expanded use of the technology worldwide.

In conjunction with the Englehardt Institute of Molecular Biology of the Russian Academy of Sciences in Moscow, Argonne has expanded its intellectual property portfolio relating to advanced biological microchip ("biochip") technology to include 55 inventions, software programs, and trademarks.

C. Outreach

Argonne works diligently to communicate its capabilities to industry, to disseminate information about technology transfer, and to facilitate access to the Laboratory's resources. The Laboratory reaches companies both directly and indirectly through state and local economic development organizations. ITD coordinates outreach activities and serves as the central point of contact for companies wishing to explore the Laboratory's capabilities and opportunities for R&D partnerships. Communications activities are coordinated closely with planning for industry partnerships. Attention focuses on eight major industrial areas: (1) transportation technology, (2) materials development, (3) process industries technology, (4) utilities technology, (5) carbon management technology, (6) biotechnology, (7) environmental stewardship, and (8) urban technology.

1. Communications Mechanisms

Argonne employs a full range of communications channels. One major channel is publication of articles in scientific and technical journals. In addition, Argonne publishes the newsletter *Tech Transfer Highlights*, which targets industry. Circulation is approximately 4,500. Participation in trade shows often involves formal Argonne exhibits. Standard public relations techniques such as press releases are employed extensively.

Argonne's web site provides extensive information about the Laboratory's research capabilities, facilities, and research programs. The ITD web site (URL: www.techtransfer.anl.gov/) links selectively to the web pages of research divisions and thus creates a Laboratory-wide site that makes accessible key areas of industrial interest. The ITD site also features information on the Laboratory's industrial partnerships — including technology transfer successes — and on awards received by the Laboratory for technology development and transfer. The Argonne Software Shop on the ITD web site features software that is already well developed and ready for licensing. The Software Shop draws much interest, and licensing discussions with several companies are under way as a result.

Each year ITD responds to approximately 2,000 inquiries from industry. ITD typically connects the inquirer with one or more Argonne researchers and then, if appropriate, guides the interaction through to negotiation and execution of an agreement. In other cases, a referral is made to an outside organization, program, or service.

2. Recognition

Argonne received several notable awards for technology development and transfer in FY 1999. *R&D* 100 awards went to (1) a technology that simultaneously reduces emissions of particulate matter and nitrogen oxides from diesel engine combustion and (2) a chemical extractor that could replace the "workhorse" of chemistry laboratories worldwide, the Soxhlet extractor.

The Argonne Clean-Diesel Technology promises to allow diesel engines to operate more cleanly and efficiently. Laboratory researchers make diesel fuel burn more completely and cleanly by adding extra oxygen to the engine's air supply under optimized engine conditions. The oxygen-rich air is separated from ambient air by using membranes that act as a chemical filter. Argonne collaborated with the chemical industry to optimize the membranes for this application. Unlike past "oxygen enrichment" techniques, the new technology reduces visible smoke and minimizes production of both particulate matter (fine-particle pollution) and oxides of nitrogen. The ability to decrease emissions of both particulates and nitrogen oxides simultaneously during combustion is a major breakthrough that has eluded researchers since the 1970s.

Argonne's Gregar Extractor represents a major advance in solvent-based chemical extraction from solid samples. The new design, available in two configurations and several sizes, eliminates problems associated with conventional Soxhlet technology and can shorten extraction times. The Gregar extractor features a revolutionary new mode of continuous extraction, and it is uniquely adjustable to serve multiple extraction applications. The extractor has been licensed to three companies.

The developers of Argonne's Ceramicrete chemically bonded ceramic were acknowledged by the Federal Laboratory Consortium in FY 2000 for their exceptional efforts in technology transfer.

Through a concerted effort by ITD outreach staff, the Laboratory in FY 2000 submitted substantially more entries to the Discover Award and *R&D* 100 Award competitions than it did in FY 1999. Eight entries were submitted for the Discover Award, compared with only one the previous year. Whereas in previous years *Discover* magazine selected approximately 45 finalists, this year that number was reduced to about 16. The Laboratory thus considers it a significant accomplishment that 1 of the 16 finalists was its froth flotation process for recovering usable plastic from mixed plastic waste. A total of 14 *R&D* 100 Award entries were submitted, compared with 5 in FY 1999. The process of creating award entries provides the Laboratory with valuable material for publicizing innovative technologies that are available for development and commercialization by industrial R&D partners.

Supplement 3: Site and Facilities

A. Description of Site and Facilities

1. Overview of Site and Facilities

Argonne National Laboratory conducts basic and technology-directed research at two sites owned by DOE. Argonne-East is located on a 1,500-acre site in DuPage County, Illinois, about 25 miles southwest of Chicago. Argonne-West is located on an 800-acre tract within the Idaho National Engineering and Environmental Laboratory (INEEL), about 35 miles west of Idaho Falls, Idaho. The facilities of Argonne-West are predominantly contained within a fenced area of about 90 acres. The only exception is the Transient Reactor Test Facility, which is located about a mile away. Argonne-West is devoted mainly to R&D on nuclear technology.

a. Argonne-East

Activities at Argonne-East support the full range of missions described in Chapter II. Major facilities at the site include the Advanced Photon Source (APS), the Laboratory's newest and largest user facility; the Intense Pulsed Neutron Source; the Argonne Tandem-Linac Accelerator System (ATLAS); and the Electron Microscopy Center for Materials Research. All these facilities are used heavily by researchers from outside Argonne. The Alpha-Gamma Hot Cell Facility supports examinations of materials for major Laboratory programs. Argonne-East also houses a full spectrum of administrative and technical support organizations, as well as DOE's Chicago Operations Office and the New Brunswick Laboratory, both of which use facilities operated and maintained by Argonne.

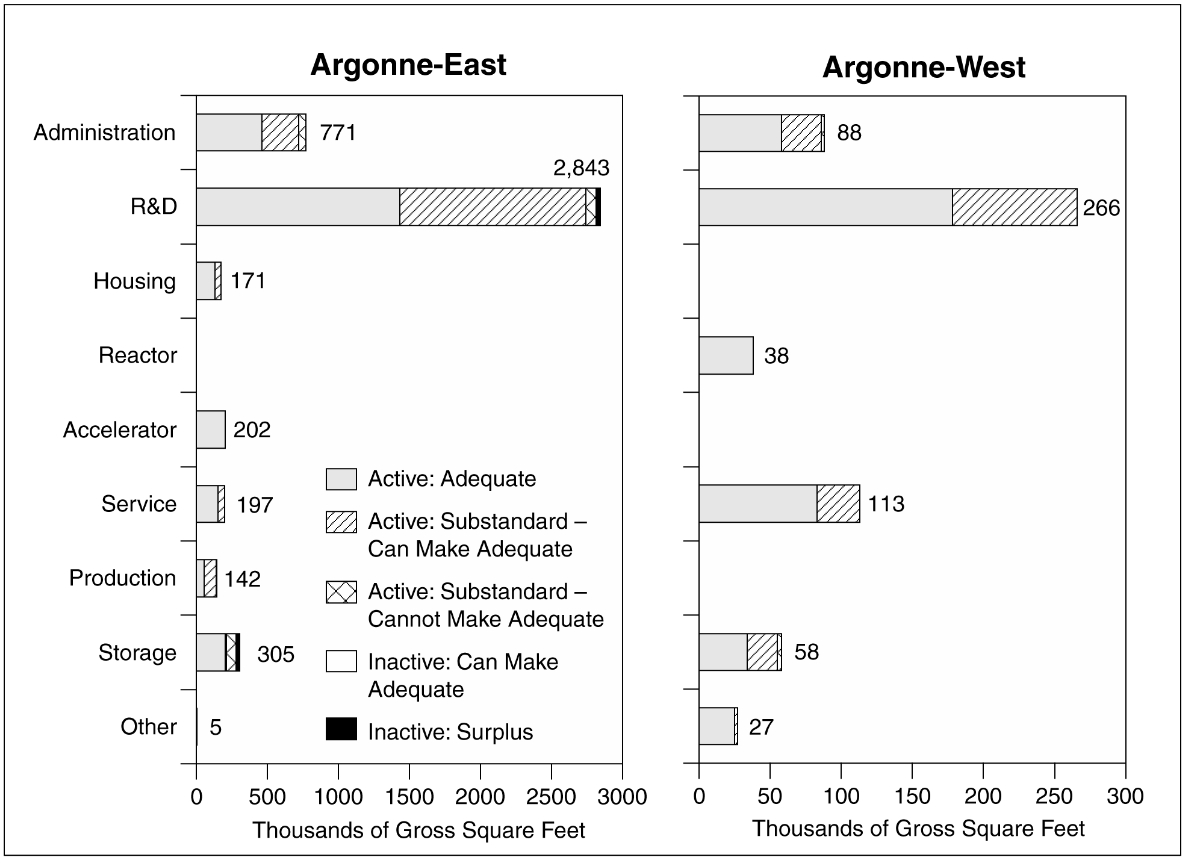
Research programs supported by DOE's Office of Science account for over half of space usage at Argonne-East. Figure S3.1 summarizes the distribution of space at Argonne-East (and Argonne-West) by functional unit (administrative, R&D, housing, and so on) and by condition of space, as a percentage of gross square footage.

Altogether, Argonne-East houses roughly 5,200 persons, including employees of DOE and contractors, visiting users of research facilities, and other guests. The Argonne-East site includes 105 buildings having 4.8 million total square feet of floor space. Nearly two-thirds of the facilities are at least 30 years old. The Laboratory also leases 77,000 square feet of office space in a commercial park near the Argonne-East site to alleviate a space shortage. (See Table S3.1, which includes the small additional amounts of space leased off-site.) Figure S3.2 summarizes the ages of Argonne-East (and Argonne-West) facilities. The replacement value of existing facilities at Argonne-East is estimated to be $1.8 billion. (See Table S3.2.)

Adequate land area is available to accommodate Argonne's plans for expanded programs in basic research and other areas. Site infrastructure generally can accommodate modest growth. Facilities are now almost fully occupied, so additional construction will be required to continue the planned removal of obsolete and deteriorated facilities and to satisfy the needs of growing programs.

b. Argonne-West

Argonne-West conducts R&D and operates facilities for DOE. After termination of the Integral Fast Reactor program in FY 1994, the programmatic mission of the Argonne-West facilities changed significantly. Current primary missions are (1) the use of electrometallurgical techniques to treat driver and blanket assemblies from the Experimental Breeder Reactor-II (EBR-II) and (2) development of technologies for deactivating other sodium-cooled reactors. In addition to Nuclear Energy, Science and Technology, DOE programs using Argonne-West facilities include Nonproliferation and National Security, Environmental Management, and Defense Programs. The most prominent programmatic facilities and their current missions are described briefly below.



	Space at Argonne-East					Space at Argonne-West		
	Active			Inactive		Active		
		Substandard					Substandard	
	Adequate	Can Make Adequate	Cannot Make Adequate	Can Make Adequate	Surplus	Adequate	Can Make Adequate	Cannot Make Adequate
Administration	463	255	53	0	0	58	28	2
R&D	1,430	1,311	71	0	31	178	88	0
Housing	130	41	0	0	0	0	0	0
Reactor [a]	0	0	0	0	0	38	0	0
Accelerator	202	0	0	0	0	0	0	0
Service	151	45	0	0	0	83	30	0
Production	52	86	5	0	0	0	0	0
Storage	203	6	71	1	25	34	21	3
Other	4	1	0	0	0	25	2	0
TOTAL [b]	2,634	1,744	200	1	55	416	169	5

[a]The reactor building at Argonne-West and some support facilities have been shut down and are being placed in an industrially safe condition.

[b]Totals and column entries were rounded independently.

Figure S3.1 Distribution of Space at Argonne-East and Argonne-West in 2000 by Function and Condition

Table S3.1 Argonne-East Space Distribution

Location	Area (thousands of square feet)
Main Site	4,769
Leased Off-Site	101
Total	4,870

The EBR-II has now been shut down and defueled. As it is being placed in an industrially safe, stable condition, it is serving as a demonstration facility for the development of deactivation methods applicable to other nuclear power plants. One key technological issue is treating EBR-II spent fuel to stabilize it from a mixed hazardous waste to a final form that will meet the requirements of a geologic repository. This problem is being addressed at the Fuel Conditioning Facility (FCF), where sodium is being removed from inside the EBR-II fuel and where the spent fuel will be converted from a mixed hazardous waste to a stable metallic and mineral waste form. A second technological issue is processing large quantities of contaminated sodium into a nonreactive waste form for disposal. A third issue is development and implementation of a safe process for controlled reaction of sodium remaining in the reactor's primary system following the draining operation.

The FCF, one of the original facilities at Argonne-West, has operated since 1964. A major refurbishment completed in 1996 made the FCF one of DOE's most modern hot cell facilities, meeting current safety and environmental requirements for handling irradiated materials, including transuranics. The FCF has two operating hot cells — one with an air atmosphere for handling contained fuel and the other with an inert argon atmosphere for conducting operations (including electrorefining) with exposed fuel materials. The FCF is the primary facility involved in applying electrometallurgical technology to preparing sodium-bonded spent nuclear fuels for ultimate disposition.

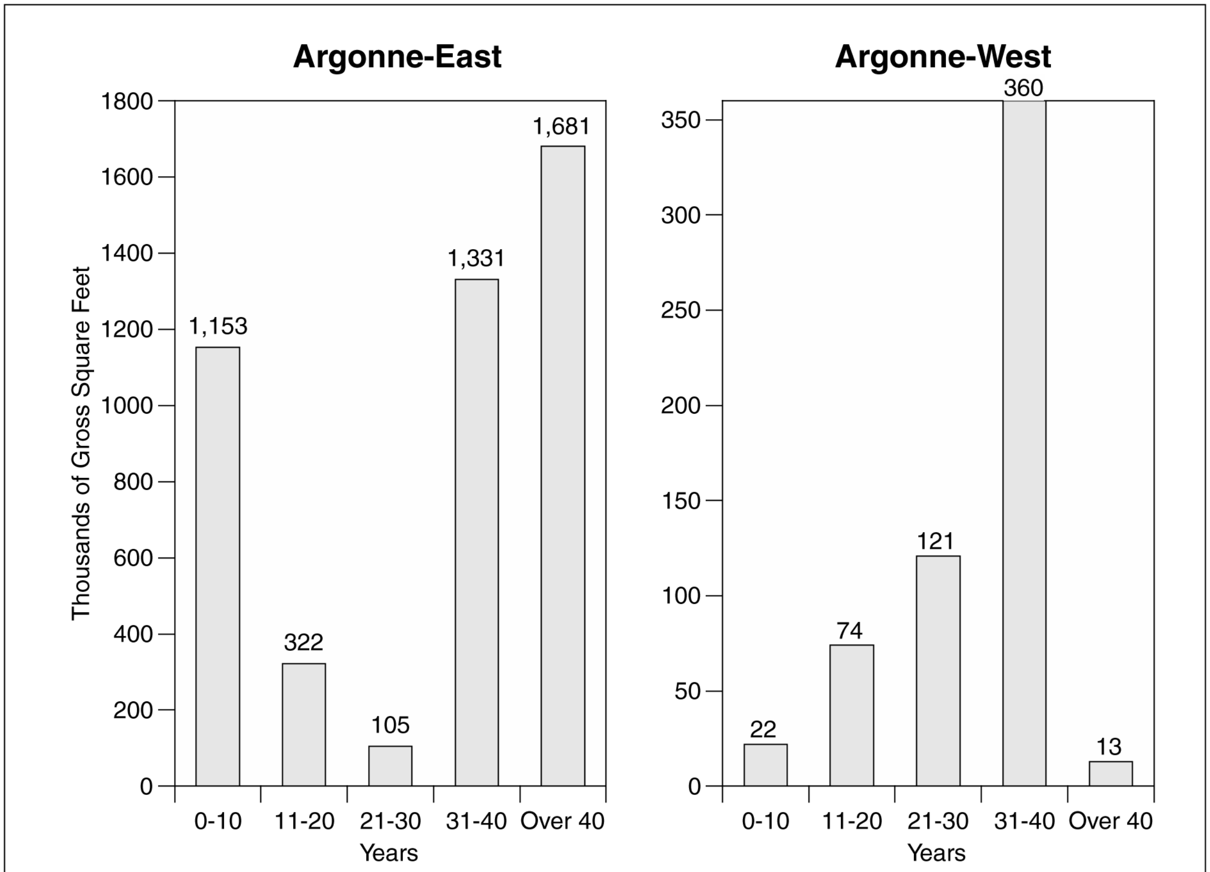
The main cell of the Hot Fuel Examination Facility (HFEF) is a large, multipurpose hot cell filled with inert gas, in which operations on highly radioactive fuels and materials can be performed. The HFEF is being used to prepare ceramic waste products as part of the treatment of sodium-bonded spent fuel. The HFEF is also used for post-irradiation testing of various irradiated fuels and materials, including spent fuel that has become degraded during storage and experimental target rods designed to determine the potential for producing tritium in commercial light-water reactors. The HFEF is an extremely versatile facility that is suitable for such work as examination (nondestructive or destructive) of radioactive materials and development of spent-fuel waste forms, as well as for other kinds of work requiring remote handling of radioactive materials. The HFEF was modified in 1999 to accept for examination fuel assemblies as long as those used in commercial reactors.

The Waste Characterization Area (WCA) within the HFEF at Argonne-West is used for sampling and characterizing waste ultimately bound for the Waste Isolation Pilot Plant (WIPP). The WCA features remote operations and glove boxes for sampling of various kinds, from gas sampling to core drilling.

The Sodium Processing Facility treats sodium from the EBR-II and other sources, converting elemental sodium to solid sodium hydroxide for ultimate disposal. Technology from the facility could be adapted to processing sodium from the Fast Flux Test Facility, the BN-350 reactor in Kazakhstan, or other sodium-cooled reactors when they are deactivated.

The Transient Reactor Test Facility (TREAT) is not currently operating, but the facility is being used to conduct various nondestructive-assay experiments with irradiated materials in containers and shielding casks. Studies now under way are considering restart of the reactor and addition of a water loop test vehicle for transient testing of advanced fuels for light-water reactors. Transient testing of defense-related components is another potential mission for TREAT.

The Zero Power Physics Reactor (ZPPR), now in standby status, was used for physics testing of new reactor core designs. The facility includes a large fuel storage vault that provides state-of-the-art storage for special nuclear materials. Associated Argonne experience in the care and treatment of special nuclear materials has been the



	Argonne-East 0-10	Argonne-East 11-20	Argonne-East 21-30	Argonne-East 31-40	Argonne-East Over 40	Argonne-West 0-10	Argonne-West 11-20	Argonne-West 21-30	Argonne-West 31-40	Argonne-West Over 40
Active	1,153	321	105	1,301	1,656	22	74	121	360	13
Inactive[a]	0	1	0	31	25	0	0	0	0	0

[a]Inactive space is too small to be displayed graphically. Entries were rounded independently.

Figure S3.2 Age of Laboratory Buildings at Argonne-East and Argonne-West in 2000

Table S3.2 Replacement Value of Argonne Facilities (millions of FY 1999 dollars)

Facilities Types	Argonne-East	Argonne-West
Buildings	1,088	234
Utilities	133	26
All Others	611	140
Total	1,832	400

basis for efforts to help the former Soviet Union with nonproliferation technology.

The Fuel Manufacturing Facility (FMF), previously used to fabricate fuel for the EBR-II, has completed manufacturing of stainless steel subassemblies for replacement purposes in the defueling of EBR-II. The FMF has glove boxes and a storage vault for special nuclear materials. Equipment for materials testing and characterization is being installed in the glove boxes to support treatment of spent fuel and stabilization of degraded ZPPR fuel plates.

Supporting the major facilities at Argonne-West is an array of shops, warehouses, laboratories, offices, and utility systems. This array of supporting facilities includes a newly refurbished Analytical Chemistry Laboratory with full capability for analyzing irradiated nuclear materials, including transuranics.

Argonne-West houses about 720 regular employees. The site includes approximately 70 buildings having 600,000 gross square feet of floor space. Most of the buildings and other infrastructure were originally built during the mid to late 1960s but have since been upgraded and expanded. Figure S3.2 summarizes the ages since original construction for Argonne-West facilities. The replacement value of existing facilities at Argonne-West is estimated to be $400 million. (See Table S3.2.)

2. Status of Existing Facilities and Infrastructure

Because most building and facility infrastructure systems have a useful-life expectancy of 25-35 years, many Argonne facilities constructed in the 1950s and 1960s require upgrading or replacement. This aging of facilities has caused the accumulation of a large inventory of needed revitalization. Furthermore, as costs related to space continue to escalate — notably heating, cooling, lighting, and maintenance — effective use of that space has become increasingly important.

Argonne's management of site and facilities includes a systematic, comprehensive program to ensure that facilities effectively meet research needs, as well as requirements for safety, health, security, and environmental acceptability. The Laboratory's ongoing facilities planning includes site development planning, condition assessment surveys, and prioritization of asset resource requirements. The following discussions for Argonne-East and Argonne-West describe the current status of each site in the context of this management program.

a. Argonne-East

The long-range planning goals at Argonne-East are to improve use of facilities, to eliminate substandard facilities, and to upgrade strategic facilities and systems. Existing space is over 98% utilized. The aggressive facilities management program at Argonne-East includes a computerized system for maintenance control and reporting. This system allows better planning of work, tighter control of resources, and more accurate measurement of results. Demolition of substandard buildings has reduced both energy costs and operating and maintenance expenses. These actions have also eliminated many unsightly areas, and cleared sites have been restored and made available for future Laboratory facilities.

The principal challenges facing Argonne-East today stem from the normal aging of buildings and infrastructure and the resulting substantial needs for updating. Nearly all substandard "temporary" facilities have been replaced. Figures S3.1 and S3.2 summarize, respectively, the condition and age of facilities at Argonne-East (and Argonne-West). As reported through the Facilities Information Management System (FIMS) via Argonne's Condition Assessment Survey process, nearly 38% of the Laboratory's buildings need major rehabilitation or upgrades. The condition of all types of buildings at the two Argonne sites is summarized in Figure S3.3 on the basis of categorization in FIMS. Overall, utility systems are adequate for anticipated needs, though selected aspects of several utilities require upgrades for compliance with standards and increased reliability. These required upgrades and rehabilitation projects include modifications of existing facilities to increase safety, health, and environmental acceptability; to save energy; and to replace obsolete building systems and thus reduce maintenance or increase reliability. In addition, some facilities require D&D (decontamination and decommissioning) or modifications to meet changing program needs or new environmental regulations.

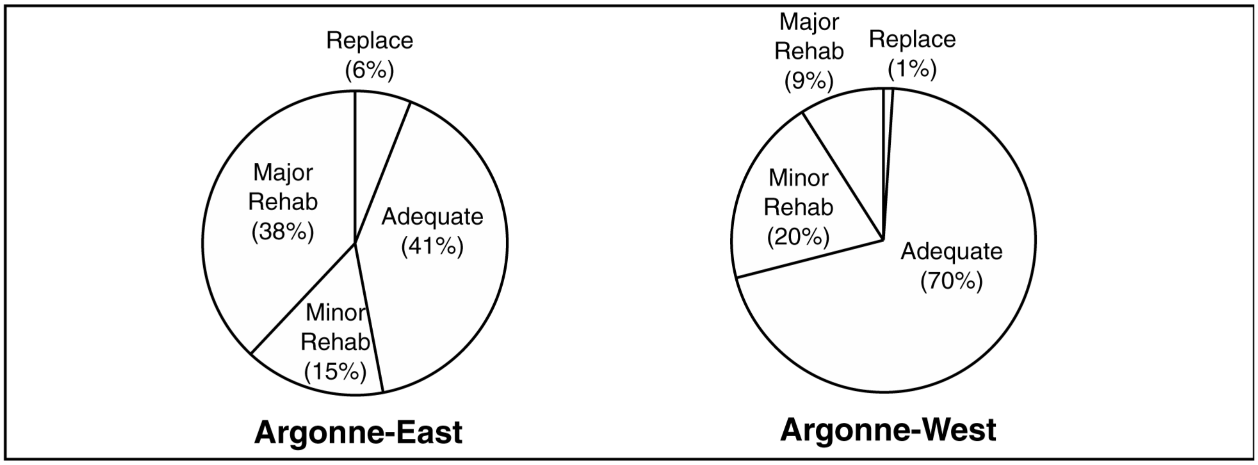


Figure S3.3 Condition Summary for Laboratory Space

b. Argonne-West

The property management program at Argonne-West aims to (1) meet the needs of the Laboratory's programs; (2) meet safety, health, and environmental requirements; (3) provide a workplace that encourages high productivity and creativity; and (4) protect the large government investment in the site's facilities.

The major programmatic facilities at Argonne-West have been well maintained, and all are projected to have useful lives of 15 years or more. General purpose facilities have been maintained in a workable state of repair with limited funds by giving priority to jobs critical or necessary to prevent much more costly future repairs. However, a backlog of needed repairs and rehabilitation that will cost several million dollars has accumulated. Figures S3.1 and S3.2 summarize the condition and age, respectively, of facilities at Argonne-West.

B. Site and Facilities Trends

Argonne manages its two sites to maximize the contribution that their physical resources make to the Laboratory's research programs and still preserve the sites' environmental settings. The central long-range management goal is to preserve past investments in capital facilities while technical and programmatic needs continue to be met.

1. Argonne-East

Managing the 4.8 million square feet of building space at Argonne-East and the supporting infrastructure as technical and programmatic needs change presents a significant challenge. Annual funding available for additions and modifications to existing facilities is not sufficient to affect the entire facility inventory significantly.

Over longer periods of time, important trends emerge. Gross square footage at Argonne-East has varied from a peak of 4.0 million square feet in 1981 (134 buildings) to a recent low of 3.6 million square feet in 1991 (104 buildings). Currently, 105 buildings provide 4.8 million square feet, after smaller facilities were replaced by larger buildings that generally are more complex and more adaptable to changing research programs. This trend largely resulted from construction of the APS (which added approximately 1.0 million square feet) and continuing disposal of small "temporary" facilities dating back half a century to the earliest years of the Laboratory. Argonne-East now, by and large, has three cohorts of buildings: the original permanent structures built in the early and mid 1950s; the complex of facilities and support areas associated with the Zero Gradient Synchrotron, from the 1960s; and the APS from the mid 1990s. Less than a tenth of assets presently on the site were constructed between 1970 and 1990. (See Figure S3.2.) Each cohort presents a different set of management challenges.

The paramount focus of Argonne management remains ensuring continued viability and enhanced safety and environmental performance for buildings of all ages, for sitewide utilities, and for other infrastructure. Figure S3.4 provides historical context for the information on the current condition of Argonne-East building space shown in Figures S3.1 and S3.3. Total square feet peaked in 1998, when active construction of APS facilities was completed. A small increase in space judged “adequate” between 1995 and 2000 reflects marginal overall improvement in the condition of the site’s buildings. From 1999 to 2000, “adequate” space declined, while “can make adequate” space increased. This recent pattern might be a first indication that existing funding levels are being strained to keep pace with backlogs of maintenance and repair needs and that those backlogs are increasing more rapidly than funding. The “inactive or surplus” category increased in 2000, when two major buildings were transferred to that status; other old, metal, or slab-on-grade structures will be similarly transferred in the near future. In addition to tracking the condition of building space through analyses like Figure S3.4, Argonne-East plans to develop similar measures and trend analyses for other site infrastructure.

Reliance on trailers to accommodate Argonne-East personnel has diminished to only a few remaining interior “office” spaces within high-bay areas. Since 1994, 52 owned or leased trailers, representing more than 45,000 gross square feet of building space, were eliminated. Also eliminated were 25 buildings representing more than 105,000 square feet of inefficient, obsolete space. Another 90,000 square feet of space is scheduled for demolition in FY 2001 as part of the Central Supply Facility construction project. Less than 2% of space at the site is unused or vacant, other than space undergoing D&D or scheduled for it.

Benchmarking the cost of maintenance by comparing total square footages is difficult because of differing mixes of ages and types of facilities. In recent years, annual maintenance funding at Argonne-East (excluding general plant project [GPP] and Multiprogram Energy Laboratories — Facilities Support [MEL-FS]) has been approximately $15 million. One positive development has been a 50% decline in urgent and emergency maintenance calls at the site between 1997 and 1999. This decline could indicate improved reliability of building equipment, reflecting increased preventive maintenance. Preventive maintenance, as opposed to corrective maintenance, rose from 33% of the total in 1997 to 43% in 1999. Continuation of increased support for infrastructure should help to maintain the reduced need for emergency maintenance as facilities age.

Between mid FY 1999 and mid FY 2000, Argonne-East disposed of one radiologically contaminated 640-square-foot facility and demolished four uncontaminated buildings totaling 42,488 square feet. Unassigned space at Argonne-East totaling slightly more than 100,000 square feet is widely scattered and therefore difficult to reassign.

Under the *Prime Contract* for operation of Argonne, performance measures related to project and infrastructure management account for a maximum of 5% of the total performance award received by the University of Chicago as the operating contractor. Also considered indirectly in determining the award are “system assessment measures,” 25% of which depends on the site’s accomplishments in the area of facilities and infrastructure.

2. Argonne-West

The Argonne-West site includes 70 buildings, 7 government-owned trailers, and 1 leased trailer, altogether having a total floor space of approximately 600,000 gross square feet. (The 8 trailers provide approximately 4,850 square feet.) Most of the buildings and infrastructure were built during the mid to late 1960s. Completed during 1998 was a new fire station (9,240 square feet). Essentially all buildings are being used, except the EBR-II Main Cooling Tower, which is scheduled for demolition. Other support facilities for EBR-II may not be needed once the reactor’s deactivation is complete. Total space at the site has increased only slightly in recent years. The expected trend is to maintain and possibly modify existing facilities for current and future missions. All trailers are currently in use, but long-run plans call for their removal.

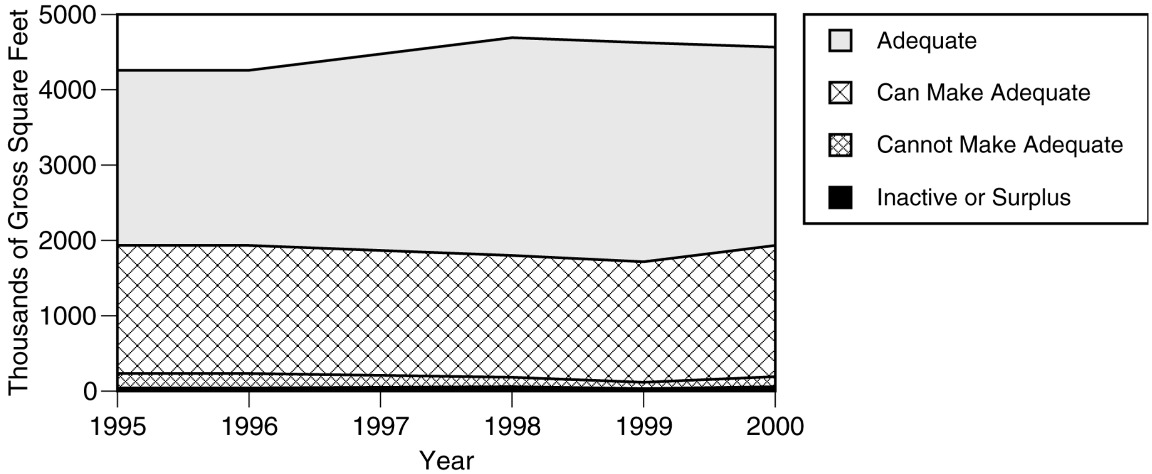


Figure S3.4 Condition of Argonne-East Buildings, 1995-2000

As Argonne-West facilities have aged, the cost of recommended maintenance has increased. However, maintenance funding received has remained stable or declined slightly.

Currently, there are no surplus facilities at Argonne-West, but that situation might change when deactivation of EBR-II is complete. All facilities at the site are presently used to support R&D programs.

C. Site and Facilities Plans

Argonne remains fully committed to its formal planning processes for site development and management of facilities. A key ongoing objective is development of a work environment that stimulates creativity and high productivity. The overriding objective of site and facilities planning is the maintenance and preservation of capital facilities while technical and programmatic needs are met. Long-range facilities planning remains flexible to accommodate changing missions and directives.

1. Argonne-East

No significant revisions to the Argonne-East site development planning framework have been necessary in recent years (URL: www.ipd.anl.gov/fy98sdp/). Scientific initiatives, including the proposed expansion of ATLAS to include the Rare Isotope Accelerator and further construction at the APS, remain confined to their dedicated areas. Continued consolidation of support service facilities in the east area of the site will free land area for future research programs.

Current programmatic planning indicates that the major challenges at the Argonne-East site over the coming decade will include improving the reliability, safety, and cost-effectiveness of the facilities that support changing programs in basic research and industrial technology. Long-range development plans for Argonne-East provide for both the Laboratory's major initiatives (described in Chapter IV) and existing programs. Planning and construction of the APS exemplify the effectiveness of the Laboratory's long-range planning. Existing Argonne-East utilities have sufficient capacity for future research initiatives, as well as current activities.

Argonne is strongly committed to collaborative research and technology transfer. Long-range site planning includes land in the east area of the site for construction of a technology transfer center. Other modifications, upgrades, or expansions of existing facilities will be undertaken as required to accommodate further programmatic initiatives.

The main issues for general purpose facilities at Argonne-East are needs to upgrade and rehabilitate facilities and infrastructures; to improve reliability and impacts to safety, health, and the environment; and to compensate for shortages of on-site space. New facilities are currently planned to support multiprogram laboratory and office activities and technology transfer. Construction of the recently funded Central Supply Facility will allow demolition of most remaining substandard facilities on the site and will provide a natural location for future consolidation of off-site personnel. (In Table S3.3, see the Multiprogram Laboratory-Office Building proposed for FY 2002 funding.) Other planned upgrades address electrical services; steam distribution and mechanical systems; fire safety improvements; various roads, sidewalks, and parking areas; and an interlocking set of improvements to building systems and spaces.

Table S3.3 (presented at the end of this section because of its length) describes recommended funding to support these efforts. The table includes all facility projects for which capital funds have been appropriated or requested and also projects that will be proposed in the near future. Projects fall into three broad categories: (1) direct support for specific programmatic objectives (listed by the DOE sponsor), (2) environmental remediation, and (3) rehabilitation of physical plant. The last category includes GPP items and MEL-FS projects. Construction funds required for proposed major initiatives are discussed in Chapter IV. In addition to support for construction, the Laboratory also requires general purpose equipment (GPE) funds, as discussed in more detail below. GPE funding significantly above recent trends is proposed in order to maintain the Laboratory's physical assets in appropriate operating condition, as well as to meet future needs and reduce the backlog of unmet needs.

2. Argonne-West

Argonne-West conducts R&D programs that support the Laboratory's overall mission in nuclear technology. Those programs currently have two major components. The first is termination of the Integral Fast Reactor program and associated activities, including shutting down EBR-II. The second component addresses issues such as the treatment of spent nuclear fuel, reactor and fuel cycle safety, and development of technologies for deactivating reactors and other nuclear facilities.

Environmental activities command high priority at Argonne. The objective of the environmental program at Argonne-West is to ensure no adverse effect to the environment and compliance with environmental regulations. Major activities include (1) replacing transformers containing polychlorinated biphenyls; (2) sampling, analyzing, and remediating past releases of hazardous materials into ponds, ditches, and other areas; (3) replacing underground pipes and tanks; (4) upgrading the radioactive scrap and waste facility with cathodic protection; (5) seeking permits from the U.S. Environmental Protection Agency and the state of Idaho for certain ongoing activities; (6) developing a facility for remotely handled mixed transuranic waste; and (7) converting elemental sodium into solid sodium hydroxide for disposal.

As funding allows, Argonne-West performs regular maintenance on its facilities and upgrades them to meet the needs of its R&D programs. Preventing deterioration of facilities and costly failures will require continued maintenance and rehabilitation of roofs, roads, sidewalks, and steam and condensate lines, as well as systems for cooling water, water supply, storm drainage, radioactive liquid waste, electricity, communications, and other purposes.

D. Detailed Plans for General Purpose Facilities

Argonne's planning for general purpose facilities focuses on maintaining facilities that are both safe and efficient.

1. Argonne-East

The Laboratory is continuing its initiative to replace deteriorated, substandard structures at Argonne-East. The Central Supply Facility now being constructed in the east area will allow removal of most remaining "temporary" facilities on the site. In the future, aging "permanent" buildings that would be inefficient for new research programs should be replaced. Argonne-East has developed plans for further upgrades of permanent laboratory and office facilities; electrical, steam, and chilled-water systems; roads and sidewalks; and the central heating plant.

Since 1998, Argonne has undertaken an annual review to integrate priorities for improving its physical plant to meet needs related to environment, safety, and health (ES&H), as well as general infrastructure requirements. This review covers all funding sources for the current year, the budget year, and the planning year. The resulting integrated project listing represents a best-faith effort by the Laboratory and DOE to define priorities that are consistent with DOE funding guidance for the three years. Those priorities, as well as requirements for later years, are reflected in Table S3.3 ("Major Construction Projects").

In addition to infrastructure needs and related health and safety requirements, environmental objectives also receive high priority at Argonne-East. Activities in this area fall into two major categories: (1) modification, replacement, or upgrading of existing processes for handling wastes and (2) cleanup of inactive contaminated facilities and sites. The Laboratory continues to implement its multiyear plans for D&D of facilities no longer in use, in order to ensure removal or containment of potential environmental hazards and to allow reuse of the facilities or the land. The Laboratory's plans for D&D of inactive surplus facilities are discussed in Section S3.E.

Efforts continue to enhance the appearance of the Argonne-East work environment, which contributes to productivity and creativity and helps to attract superior scientists and engineers. Projects include renovation of many public areas, improvement of landscaping and parking areas, and general enhancement of the site's appearance to reflect its status as a world-class research facility.

Maintenance of facilities at Argonne-East — along with rehabilitation, D&D, demolition, and site enhancement — continues to receive high priority. By directing resources to their most effective applications, the maintenance process maximizes the resulting improvements in efficiency and productivity. Argonne inspects its facilities through a formal Condition Assessment Survey process. The Laboratory maintains a management information system for work requests and for processing of backlog information to achieve better integration of tasks and use of resources.

2. Argonne-West

At Argonne-West, the main issue for general purpose facilities is facility aging, with its normal attendant requirements for upkeep and renovation. Now being planned are facility additions and modifications required for programmatic support, including environmental activities, waste handling, and related efforts. Correction of facility-related deficiencies is also a planning focus.

E. Facilities Resource Requirements

Argonne has historically received only part of the funding needed for construction of infrastructure improvements and replacement facilities and for remediation and upgrades to correct ES&H and other deficiencies. Table S3.3 describes all facility projects for which capital funds have been appropriated or requested, as well as projects that will be proposed in the near future.

1. Argonne-East

Funding through the MEL-FS and GPP programs has allowed Argonne-East to replace or rehabilitate key elements of the site's infrastructure and many severely deteriorated facilities. These facilities serve a wide variety of changing programmatic missions and national user facilities, as well as support services and administrative functions needed to carry out the broad mandate of a multiprogram laboratory. Except for Building 350, which is dedicated solely to the New Brunswick Laboratory, the ability of facilities to continue functioning safely, efficiently, and economically depends on sustained infrastructure support from DOE facilities funding. DOE-Environmental Management funding for environmental remediation and for D&D projects has also supplemented the broad infrastructure support from DOE over the last decade.

a. MEL-FS Program Support

Funding for upgrading or replacing substandard facilities at Argonne-East has generally been provided through the MEL-FS program. Additional funding is needed to further rehabilitate building systems in permanent office and laboratory buildings; to upgrade various utility systems, especially those critical to reliability of service and continued environmental safety; and to provide suitable space for support activities.

A small number of substandard structures remain in use. Removal of old supply facilities in the east area of the site will be completed when they are replaced by the Central Supply Facility in FY 2001. Additional funding will be needed to dispose of or replace a few other obsolete structures.

Argonne-East has developed plans to modify, replace, or upgrade existing facilities and to correct deficiencies by using an integrated approach to considering ES&H and infrastructure needs. Increased funding will be needed to meet both ES&H demands and facility needs. Adequate funding prevents premature deterioration or failure of facilities and systems resulting from deferred maintenance or repairs and also ensures compliance with existing and new environmental regulations and permits. These issues are particularly relevant for a series of proposed line-item projects described in Table S3.3, which include upgrades and modernization of building electrical and mechanical systems and their controls, as well as laboratory space upgrades. Other important projects address fire safety improvements; asbestos abatement; upgrading the sitewide civil infrastructure; and improvements to the central heating plant, chillers, steam distribution system, and electrical distribution system.

b. General Plant Projects

General plant projects funding supports environmental compliance projects, near-term infrastructure improvements, and key safety upgrades. In general, GPP funds are crucial for work that goes beyond the short-term maintenance and repair needed to keep plant and equipment operational but that must be undertaken before the normal lead times for MEL-FS construction projects would allow funding from that source. Historically, GPP funding at Argonne-East has been inadequate. Table S3.3 reflects requests for significant increases.

The GPP funding required at Argonne-East is directly related to the age and condition of the site's plant and the need to protect employees, the public, and the environment. Current annual funding of $4.8 million meets only a small portion of the most critical needs. Since FY 1999 the Laboratory has identified GPP requirements exceeding $23 million over the immediate three-year budget period. These funds support plant upgrades and also contingency funding for needs too urgent to be delayed until line-item funding becomes available.

c. General Purpose Equipment Funding

In order for Argonne to serve DOE as a premier multiprogram laboratory, its support infrastructure must include equipment that allows efficient performance. GPE funds are the Laboratory's primary resource for purchasing equipment needed for vital support activities such as (1) plant maintenance; (2) health and safety activities; (3) monitoring and control of effluents to the environment; (4) motor vehicle services; (5) technological support, including administrative computing, machine shops, electronics support, and analytical chemistry; and (6) administrative functions, including human resources, procurement, and accounting.

At Argonne-East, insufficient GPE funding over the past decade has led to serious aging and obsolescence of equipment for support activities and an inability to introduce needed major new equipment in a timely manner. Substantially greater GPE funding is needed to support challenging programmatic and site-related initiatives. The funding program currently approved by DOE for Argonne-East (Table S3.4) allows $1.6 million in FY 2000 for GPE, but a total of $6 million is required for immediate critical needs. The funding shortfall prevents orderly replacement of obsolete and inefficient equipment, a process needed to reduce a serious backlog of equipment needs that has accumulated during a decade of underfunding. The Laboratory's emphasis on additional safety and environmental activities — particularly responses to self-assessments and corrective actions to meet expanding DOE, federal, and state requirements — has diverted resources and increased the backlog of needs in other areas.

Table S3.4 Projected General Purpose Equipment Funding for Argonne-East ($ in millions BA)

FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06
1.6	1.6	2.2	2.5	2.8	3.2	3.5	4.0

d. Maintenance Funding

Deferred maintenance of real property for Argonne-East in FY 1999 (as reported in the FIMS database) includes $11.1 million for buildings (representing 1.0% of replacement plant value) and an additional $1.7 million for utilities and infrastructure (representing 1.2% of replacement plant value). Annual expenditures in recent years of approximately $22 million for maintenance have been sufficient to maintain the site's physical plant in satisfactory operating condition. However, additional funds are required for less urgent maintenance tasks that have accumulated in the deferred maintenance backlog and are important for efficient operation of the Laboratory in the long run.

2. Argonne-West

As facilities at Argonne-West age, a high priority is progress each year toward replacement and refurbishment of various facility systems. Funding of about $2 million is needed annually for the normal maintenance, repair, and upgrades that keep facilities functional and in compliance with escalating requirements in areas such as safety and environmental protection.

The GPP funding requirements at Argonne-West are affected by the age and condition of the plant and by continuing concern for the protection of employees, the public, and the environment. Throughout the last decade, GPP funding was well below requested levels. As a consequence, many needs were deferred, and a backlog was created. Adequate GPP funding will prevent premature deterioration or failure of facilities and systems resulting from deferred repair and will also ensure compliance with ES&H regulations and permits.

F. Assets Management, Space Management, and Inactive Surplus Facilities

In partnership with DOE, Argonne plans for, acquires, operates, maintains, and disposes of physical assets as valuable national resources. This stewardship of physical assets to meet the Laboratory's mission is accomplished in a cost-effective manner. The associated planning process integrates programmatic, ecologic, economic, cultural, and social factors; considers the site's larger regional context; and involves stakeholder participation.

1. Assets Management

Argonne's assets are acquired, rehabilitated, and upgraded to support the Laboratory's mission. DOE executes all real estate acquisitions through a Department-certified real estate specialist. All modifications and improvements are designed and constructed in compliance with applicable state, regional, and national building codes. Central considerations in design and construction are maintainability, operability, life cycle costs, and configuration integrity. Tools such as value engineering and trade-off analysis are used to improve the efficiency and cost-effectiveness of the Laboratory's acquisition of physical assets. The principles and practices of Integrated Safety Management are fully integrated into the Life Cycle Asset Management processes by which Argonne implements site improvements, resulting in a safe work environment through safe work practices.

The DOE corporate physical assets database — FIMS — includes a current inventory of the Laboratory's physical assets. Periodically, this inventory is systematically reviewed, and the condition of the assets is assessed. Argonne determines the maintenance and associated funding required to keep its assets functioning effectively. The Laboratory's work management system provides for the maintenance (preventive, predictive, and corrective) required to keep assets available to serve their planned missions. This process also ensures that assets are readied for disposal when appropriate. Backlogs associated with maintenance, as well as with repairs and capital improvements, are managed through a systematic prioritization process. Energy usage and utility services are also managed efficiently and effectively. Integrity of all physical assets and systems is ensured through a configuration management process.

Surplus facilities identified through the Laboratory's planning process are reported to DOE in a timely manner. Assets are transferred between program offices through the process established by DOE. Disposal of real estate is subject to DOE approval. For the disposition of nuclear facilities, the Laboratory develops a decommissioning turnover plan and, if appropriate, a decontamination plan. A deactivation readiness review is completed before any physical work begins.

2. Space Management

Argonne-East has long used a system of space charges that facilitates the allocation of annual infrastructure costs among various users. Occupants are assessed for costs on the basis of their use of assignable building space (which does not include general passageways, docks, or space for building equipment and mechanical systems). Space charges include recovery of sitewide expenditures for grounds, road repairs, snowplowing, and other general utility and maintenance services. Building-specific charges reflect historical levels of maintenance for that particular building, custodial costs, and expenses for services such as sewer, water, electricity, and steam. Within buildings, services to production facilities, dedicated scientific and research apparatus, and other special-purpose equipment are metered separately for direct billing to users.

Maintenance and surveillance of inactive surplus facilities do not currently constitute a significant issue at Argonne-East, because virtually all facilities are operational or undergoing, at most, partial D&D. Building disposals have occurred regularly, as discussed above. The majority of these actions have not involved contamination issues other than asbestos.

3. Inactive Surplus Facilities

Inactive surplus facilities present significantly different challenges for the two Argonne sites, as discussed below.

a. Argonne-East

Argonne-East, in collaboration with the DOE Chicago Operations Office, has developed a program for the timely D&D of facilities no longer in use at the site, in order to ensure appropriate removal or containment of potential environmental hazards and to allow reuse of facilities where warranted. DOE-Environmental Management (DOE-EM) funds this program.

Several major D&D projects were recently completed. After completion of work at the Experimental Boiling Water Reactor in Building 331, the building was converted to a transuranic waste storage facility, resulting in substantial savings compared to new construction. More than 60 surplus glove boxes in Building 212 were decontaminated and downsized. Appropriate waste was packaged and sent to the Hanford site; remaining transuranic waste will be stored in the new Building 331 facility. Argonne research programs are now using offices and laboratories in the area housing the glove boxes. Seven of the hot cells in the M-Wing of Building 200 were decontaminated sufficiently to reduce radon releases, which previously caused more than 95% of off-site exposure. The cells are now available for future use. D&D of the Fast Neutron Generator (Building 314) was completed, and the area is being used for general support services. D&D of the JANUS reactor (Building 202) and the Argonne Thermal Source Reactor (Building 316) was completed, and the facilities are now available for reuse. After D&D, the Waste Ion Exchange Facility (Building 594) was demolished.

D&D of the CP-5 Reactor will be completed in 2000. This D&D program has been combined with the CP-5 Large Scale Demonstration Program. The combined program, under the direction of the Strategic Alliance for Environmental Restoration (including Argonne, Commonwealth Edison, Duke Engineering and Services, Florida International University, ICF-Kaiser, and 3M) demonstrated 23 new D&D technologies. No further cost-effective reuse of the CP-5 facility has been identified. Although the currently approved DOE-EM baseline does not include funding for demolition, the facility should be demolished when D&D activities are complete. The D&D of the 60-Inch Cyclotron (in Building 211) should be completed in early 2001. Zero Power Reactors 6 and 9 (in Building 315), the Juggernaut Reactor, surplus retention tanks in Building 310, and the Building 301 hot cells are identified for future D&D funding.

More than half of the D&D work identified in the DOE-EM baseline for Argonne-East has been completed. All D&D activities identified in the approved baseline will be completed by the end of FY 2003 if the specified funding is provided.

Surplus facilities that are not contaminated have also been a long-standing concern at Argonne-East. During the 1980s the Laboratory added roughly 300,000 gross square feet of new space, but demolition of substandard buildings and removal of temporary trailers caused a net overall loss of 270,000 square feet. Since 1990 Argonne has removed more than 100,000 additional square feet. The recent removal of Building 207 will facilitate expansion of the ATLAS complex. Removal of facilities from the old 800 area is nearing completion, as is replacement of remaining "temporary" supply facilities in the east area, which should be completed in FY 2001. After construction of the Central Supply Facility, emphasis will shift from demolition in the east and west areas of the site to selective removal of permanent, single-purpose buildings that can no longer function efficiently. Current Laboratory plans call for the release of 77,000 square feet of leased off-site space by FY 2004, contingent on construction of suitable replacement space. The Laboratory will continue to remove abandoned or disconnected mechanical equipment, such as chillers. In addition, approximately 5,000 square feet of further space in obsolete metal buildings in the 360 area and in three abandoned scientific structures in the 400 area will be removed during FY 2000 through the use of operating funds.

After baseline DOE-EM disposals have been completed, candidates for subsequent acceptance into the DOE-EM disposal program include Buildings 330 and 301, for which no economically viable continued use is foreseen. Other candidates include parts of buildings, such as the M-Wing hot cells in Building 200 and the H-Wing high bay areas in Building 205.

b. Argonne-West

Currently, all facilities at Argonne-West are actively used, including many EBR-II systems that provide power switching, site monitoring, cooling water, compressed air, and other services to the entire site. Once deactivation of EBR-II is complete, some associated facilities that do not provide such sitewide services may be classified as surplus if they are not used for other programs. The EBR-II Main Cooling Tower is no longer needed; because of its poor condition, it has no surplus value and will be demolished.

G. Energy Management

Energy efficiency and conservation are strong priorities at Argonne.

1. Argonne-East

Argonne-East is conducting detailed studies of its energy usage and is retrofitting facilities for improved energy management. Strategies being considered to reduce energy costs further include energy savings performance contracting and competitive procurement of electricity from deregulated utilities. The Laboratory is also benefiting from participation in the demand-side load management program of its electric utility, Commonwealth Edison.

Argonne spends over $12.6 million each year to purchase energy supplies: approximately $10.5 million for electricity, $1.5 million for natural gas, and $0.6 million for coal. Natural gas currently provides about 70% of the fossil energy used for steam production; coal provides the rest. Electricity rates have been constant for the last two years, and Commonwealth Edison has publicly indicated that it will maintain the same rates for the next five years, as deregulation of the electric utility proceeds. Natural gas costs are generally increasing. Wellhead prices, which fluctuate considerably, recently reached new highs.

The Laboratory's current electric utility contract is based on the area-wide agreement reached by Commonwealth Edison and the General Services Administration. As a result of industry deregulation, natural gas is supplied through two contracts. Gas is first delivered to the Chicago "city gate" through a Defense Logistics Agency supply and transportation contract. Thereafter, the gas is distributed to Argonne by Northern Illinois Gas, which also provides gas storage services. All site utility contracts are held by DOE's Argonne Group.

As experimental activity increases at the APS, the Laboratory's electricity consumption is forecast to grow by about 20%. The Laboratory expects that overall cost savings of 10-15% can be achieved from a projected maximum power load exceeding 40 megawatts, in conjunction with the contract held by DOE's Argonne Group. Argonne is also aggressively pursuing third-party financing of energy conservation retrofits, taking advantage of momentum from the former In-House Energy Management program. To date, Argonne-East is well ahead of schedule in achieving the 30% reduction in energy usage by FY 2005 and the 35% reduction by FY 2010 mandated by executive order. By FY 2005, the Laboratory expects to have completed all necessary site energy audits and implementation of cost-effective energy conservation projects that the audits identify. The Laboratory has reduced the cost of the natural gas purchased for the boiler plant by taking advantage of its position along competing interstate gas pipelines and the option of by-pass service from the local gas supplier. In order to avoid high costs on days when the gas supply is restricted because of weather or service interruptions, Argonne procures a supply of gas at a firm price and uses available storage options to ensure the fuel's availability. Argonne-East also achieves savings in coal purchases, which are trucked to the site. (Additional information on facility-specific energy and building use is available on the Web [URL: www.anl.gov/PFS/pfshome.html], through a "Building and Utility Data Summary" link.)

2. Argonne-West

Argonne-West has historically managed its energy consumption aggressively. Already met or exceeded are the following "Energy Performance Goals for Federal Buildings": (1) Energy consumption per gross square foot by the year 2000 is 20% less than the energy consumption per gross square foot in the baseline period of FY 1985. (2) Energy consumption per gross square foot by the year 2005 is 30% less than the energy consumption per gross square foot in FY 1985.

Shutdown of EBR-II on October 3, 1994, eliminated the ability of Argonne-West to generate its own electrical power and export electricity to the INEEL distribution grid. Because of limited resources, no studies or surveys to identify opportunities for additional energy conservation have been conducted.

Table S3.3 Major Construction Projects[a] ($ in millions BA)

	TEC	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Funded Projects									
KB-02									
Office of Science									
Nuclear Physics									
Accelerator Improvements, ANL-East[b]	0.8	0.4	0.4	-	-	-	-	-	-
39-KC-02									
Office of Science									
Basic Energy Sciences									
Materials Sciences									
Advanced Photon Source, Accelerator Improvements, ANL-East[b]	7.5	4.4	3.1	-	-	-	-	-	-
KC-03									
Office of Science									
Basic Energy Sciences									
Chemical Sciences									
General Plant Projects, ANL-East[b]	10.9	5.6	5.3	-	-	-	-	-	-
39-KG-01									
Office of Science									
Multiprogram Energy Laboratories — Facilities Support									
General Purpose Facilities									
Central Supply Facility (MEL-001-006)	5.9	1.9	3.4	0.6	-	-	-	-	-
39-KG-02									
Office of Science									
Multiprogram Energy Laboratories — Facilities Support									
Environment, Safety, and Health Support									
Building Electrical Service Upgrade - Phase I, ANL-East (96-E-330)	7.9	0.3	-	-	-	-	-	-	-
Electrical System Upgrade - Phase III (MEL-001-003)	7.6	5.0	1.2	-	-	-	-	-	-
Fire Safety Improvements - Phase IV (MEL-001-009)	8.4	-	0.4	6.0	2.0	-	-	-	-
TOTAL FUNDED PROJECTS	49.0	17.6	13.8	6.6	2.0	0.0	0.0	0.0	0.0

Table S3.3 Major Construction Projects[a] (Cont.)

	TEC	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Budgeted Projects									
KB-02									
Office of Science									
Nuclear Physics									
Accelerator Improvements, ANL-East[b]	0.4	-	-	0.4	-	-	-	-	-
KC-02									
Office of Science									
Basic Energy Sciences									
Materials Sciences									
Advanced Photon Source, Accelerator Improvements, ANL-East[b]	4.1	-	-	4.1	-	-	-	-	-
KC-03									
Office of Science									
Basic Energy Sciences									
Chemical Sciences									
General Plant Projects, ANL-East[b]	10.1	-	-	10.1	-	-	-	-	-
KP-11									
Office of Science									
Biological and Environmental Research									
Life Sciences									
General Plant Projects, ANL-East[b]	3.0	-	-	3.0	-	-	-	-	-
SO									
Office of Security and Emergency Operations									
General Plant Projects, ANL-West (Security Upgrade)[b]	1.0	-	-	1.0	-	-	-	-	-
TOTAL BUDGETED PROJECTS	18.6	0.0	0.0	18.6	0.0	0.0	0.0	0.0	0.0
TOTAL FUNDED AND BUDGETED PROJECTS	67.6	17.6	13.8	25.2	2.0	0.0	0.0	0.0	0.0
Proposed Projects									
39-AF-95									
Office of Nuclear Energy, Science and Technology									
Nuclear Energy Research and Development									
General Plant Projects, ANL-West[b]	5.5	-	-	-	-	1.0	1.5	1.5	1.5
Remote Treatment Facility, ANL-West	70.0	-	-	-	-	10.0	20.0	25.0	15.0
KB-02									
Office of Science									
Nuclear Physics									
Accelerator Improvements, ANL-East[b]	3.0	-	-	-	0.6	0.6	0.6	0.6	0.6

Table S3.3 Major Construction Projects[a] (Cont.)

	TEC	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Proposed Projects (Cont.)									
KC-02									
Office of Science									
Basic Energy Sciences									
Materials Sciences									
Advanced Photon Source, Accelerator Improvements, ANL-East[b]	42.0	-	-	-	8.4	8.4	8.4	8.4	8.4
KC-03									
Office of Science									
Basic Energy Sciences									
Chemical Sciences									
General Plant Projects, ANL-East[b]	44.6	-	-	-	7.9	9.0	9.0	9.2	9.5
39-KG-01									
Office of Science									
Multiprogram Energy Laboratories — Facilities Support									
General Purpose Facilities									
Building Replacement, Multiprogram Laboratory-Office Building (02-CH-007)	12.0	-	-	-	1.0	10.5	0.5	-	-
General Purpose Laboratory Facility	5.5	-	-	-	-	-	5.5	-	-
Building Rehabilitation and Upgrade									
Laboratory Space Upgrade - Phase I	19.7	-	-	-	-	19.7	-	-	-
Building Mechanical and Control Systems Upgrade - Phase II	9.2	-	-	-	-	9.2	-	-	-
Building Electrical Service Upgrade - Phase III	6.2	-	-	-	-	6.2	-	-	-
Building Mechanical and Control Systems Upgrade - Phase III	9.2	-	-	-	-	-	9.2	-	-
Building Electrical Service Upgrade - Phase IV	6.2	-	-	-	-	-	6.2	-	-
Building Mechanical and Control Systems Upgrade - Phase IV	8.2	-	-	-	-	-	-	8.2	-
Laboratory Space Upgrade - Phase II	8.2	-	-	-	-	-	-	8.2	-
Building Roof Replacement	8.0	-	-	-	-	-	-	8.0	-
Building Electrical Service Upgrade - Phase V	6.2	-	-	-	-	-	-	6.2	-
Laboratory Space Upgrade - Phase III	8.2	-	-	-	-	-	-	-	8.2
Rehabilitation and Upgrade of Utility Distribution Systems									
Steam System Upgrade - Phase I	7.9	-	-	-	-	7.9	-	-	-
Central Heating Plant Upgrade - Phase II	12.0	-	-	-	-	12.0	-	-	-
Roads/Parking/Walks/Street Lighting Upgrade	9.7	-	-	-	-	-	9.7	-	-
Electrical System Upgrade - Phase IV	6.5	-	-	-	-	-	-	6.5	-

Table S3.3 Major Construction Projects[a] (Cont.)

	TEC	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Proposed Projects (Cont.)									
39-KG-02									
Office of Science									
Multiprogram Energy Laboratories — Facilities Support									
Environment, Safety, and Health Support, ANL-East									
Mechanical and Control Systems Upgrade - Phase I (02-CH-056)	9.1	-	-	-	0.7	6.7	1.7	-	-
Building Electrical Service Upgrade - Phase II (02-CH-062)	8.3	-	-	-	0.5	2.8	5.0	-	-
Replacement/Conversion of Chillers Using Class I Refrigerants	6.0	-	-	-	-	6.0	-	-	-
Fire Safety Improvements - Phase V	6.0	-	-	-	-	6.0	-	-	-
Sitewide Asbestos Abatement - Phase I	5.6	-	-	-	-	-	5.6	-	-
SO									
Office of Security and Emergency Operations									
General Plant Projects, ANL-West (Security Upgrade)[b]	3.0	-	-	-	2.0	1.0	-	-	-

[a]This table excludes construction funded from non-DOE sources.

[b]Supported by operating funding.

Supplement 4: Other Charts and Tables

This supplement contains charts and tables characterizing Argonne's activities in the following areas:

- Science and math education
- User facilities
- Human resources
- Subcontracting and procurement

A. Science and Math Education

Table S4.1 characterizes Argonne's existing educational programs. The total number of appointments and the number of minorities and women are shown for FY 1998 and FY 1999.

B. User Facilities

Table S4.2 describes experimenters at the Argonne user facilities that have been officially designated as such by DOE. In highly abbreviated terms, these facilities provide the following important scientific capabilities:

- *Advanced Photon Source:* Became operational in 1996, providing superintense X-ray beams meeting research needs in virtually all scientific disciplines and many critical technology areas; accommodates national research centers in basic energy sciences, advanced synchrotron radiation instrumentation, and structural biology, as well as academic and industrial research teams.

- *Intense Pulsed Neutron Source:* Accelerates protons to obtain neutrons, which are particularly valuable for the study of materials through analysis of the motions and structures of atoms.

- *Argonne Tandem-Linac Accelerator System:* Accelerates ions of heavy elements for studies of their reactions, to advance basic understanding of the properties of atoms and atomic nuclei.

- *Electron Microscopy Center for Materials Research:* Provides transmission and scanning electron microscopy for high-spatial-resolution imaging, microanalysis, and *in situ* studies, including studies of *in situ* ion irradiation and implantation effects in metals, semiconductors, and ceramics.

C. Human Resources

Argonne's employees are highly educated. Table S4.3 summarizes the academic degrees held by permanent staff at the end of FY 1999. Table S4.4 describes the distribution of Argonne employees among various racial and ethnic categories.

D. Subcontracting and Procurement

Table S4.5 describes Argonne's subcontracts and procurements from universities. Table S4.6 describes procurements from small or disadvantaged businesses.

Table S4.1 Participation in Science and Math Educational Programs

	FY 1998			FY 1999			
Program	Total	Under-represented Minorities[a]	Women	Total	Under-represented Minorities[a]	Women	FY 2000 Projected Total
Students							
Instructional Laboratory[b]	708	277	379	2,605	400	1,112	3,000
Instructional Vehicle	11,604	5,463	5,839	4,408	1,506	2,164	7,000
Student Conference	428	-	415	362	-	350	400
Teachers							
Internet Training	175	25	100	238	17	178	250
Argonne Community of Teachers	50	7	38	50	7	38	50
Microscale Chemistry	53	12	27	16	4	6	-
Educational Network Consortium	6,081	-	-	6,375	-	-	7,000
Undergraduate Programs							
Summer Energy Research Fellowship Program	220	19	71	210	13	77	220
Semester Energy Research Fellowship Program	83	12	32	68	9	25	70
Undergraduate Research Symposium	187	-	-	130	-	-	150
Student Interdisciplinary Research Training	13	13	9	12	12	6	15
Graduate Programs							
Thesis Graduate Students	179	5	51	158	2	47	160
Postdoctoral Fellows	216	5	38	207	5	28	210
National School on Neutron and X-ray Scattering	-	-	-	47	1	9	60
Faculty Programs							
Faculty Research Participation	33	4	6	25	6	2	30
Sabbatical Leave	9	1	3	5	1	1	6
Faculty Visits	36	4	4	31	2	5	30

[a]Underrepresented minorities include African-Americans, Hispanics, and Native Americans.

[b]Instructional Laboratory numbers for FY99 and beyond include all levels. Numbers for FY98 include only undergraduates.

Table S4.2 Experimenters at Designated Argonne User Facilities — FY 1999

User Affiliation	Number of Individual Experimenters	Number of Organizations Represented	Percent of Use[a]
Advanced Photon Source			
Argonne	188	1	25
Other DOE Laboratories	41	8	3
Non-DOE U.S. Government	17	3	5
U.S. Universities	643	85	35
U.S. Industry	132	27	21
Foreign Government Laboratories	17	7	1
Foreign Universities	115	46	8
Foreign Industry	2	1	1
Other	67	17	1
Total	1,222	195	100
Intense Pulsed Neutron Source[b]			
Argonne	65	1	31
Other DOE Laboratories	21	5	10
Non-DOE U.S. Government	0	0	0
U.S. Universities	93	43	45
U.S. Industry	6	3	3
Foreign Government Laboratories	6	5	3
Foreign Universities	16	9	7
Foreign Industry	1	1	1
Other	0	0	0
Total	208	67	100
Argonne Tandem-Linac Accelerator System			
Argonne	41	1	38
Other DOE Laboratories	28	5	12
Non-DOE U.S. Government	0	0	0
U.S. Universities	85	23	35
U.S. Industry	0	0	0
Foreign Government Laboratories	21	9	3
Foreign Universities	76	24	12
Foreign Industry	0	0	0
Other	0	0	0
Total	251	62	100
Electron Microscopy Center for Materials Research			
Argonne	51	1	47
Other DOE Laboratories	13	4	13
Non-DOE U.S. Government	2	2	2
U.S. Universities	29	12	20
U.S. Industry	0	0	0
Foreign Government Laboratories	11	6	9
Foreign Universities	14	9	9
Foreign Industry	0	0	0
Other	0	0	0
Total	120	34	100

[a]Percentage of experimental activity or use. Time devoted to maintenance or upgrading of the facility is not included.

[b]For the Intense Pulsed Neutron Source, the percent of use was calculated from the numbers of individual users, not from experimental time.

Table S4.3 Academic Degrees of Argonne Staff[a]

Occupational Category	Total	PhD	MS/MA	BS/BA	Other[b]
Officials and Managers	514	230	119	96	69
Scientists	589	310	128	114	37
Engineers	630	226	165	164	75
Managers and Administrators	299	33	71	107	88
Technicians	570	0	3	69	498
All Others	992	0	1	50	941
Laboratory Total	3,594	799	487	600	1,708

[a]Number of full- and part-time regular employees at the end of FY99.

[b]Associate level degree or less.

Table S4.4 Population of Laboratory Employees[a]

Occupational Category	Total				Minority Total				White			
	Male		Female		Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Officials and Managers	428	83.3	86	16.7	38	7.4	8	1.6	390	75.9	78	15.2
Scientists and Engineers	1,059	86.9	160	13.1	142	11.6	25	2.1	917	75.2	135	11.1
Managers and Administrators	137	45.8	162	54.2	11	3.7	22	7.4	126	42.1	140	46.8
Technicians	505	88.6	65	11.4	48	8.4	9	1.6	457	80.2	56	9.8
Clerical Workers	16	3.6	433	96.4	3	0.7	69	15.4	13	2.9	364	81.1
Craftsmen and Laborers	348	90.2	38	9.8	59	15.3	19	4.9	289	74.9	19	4.9
Service Workers	115	73.2	42	26.8	30	19.1	13	8.3	85	54.1	29	18.5
Totals	2,608	72.6	986	27.4	331	9.2	165	4.6	2,277	63.4	821	22.8

Occupational Category	Black				Hispanic				Native American				Asian			
	Male		Female		Male		Female		Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Officials and Managers	4	0.8	3	0.6	4	0.8	2	0.4	1	0.2	0	0.0	29	5.6	3	0.6
Scientists and Engineers	11	0.9	2	0.2	17	1.4	3	0.2	2	0.2	0	0.0	112	9.2	20	1.6
Managers and Administrators	5	1.7	8	2.7	2	0.7	6	2.0	1	0.3	1	0.3	3	1.0	7	2.3
Technicians	23	4.0	3	0.5	13	2.3	0	0.0	2	0.4	1	0.2	10	1.8	5	0.9
Clerical Workers	2	0.4	38	8.5	1	0.2	21	4.7	0	0.0	1	0.2	0	0.0	9	2.0
Craftsmen and Laborers	43	11.1	14	3.6	12	3.1	2	0.5	1	0.3	2	0.5	3	0.8	1	0.3
Service Workers	21	13.4	6	3.8	4	2.5	5	3.2	3	1.9	1	0.6	2	1.3	1	0.6
Totals	109	3.0	74	2.1	53	1.5	39	1.1	10	0.3	6	0.2	159	4.4	46	1.3

[a]Includes both full-time and part-time regular employees at the Illinois and Idaho sites, as of September 30, 1999.

Table S4.5 Total External Subcontracting and Procurement ($ in millions)

Source	FY 1999	FY 2000	FY 2001	FY 2002
Universities	9.7	6.7	6.8	6.9
All Other	124.0	103.3	103.2	103.1
Transfers to Other DOE Facilities	11.0	15.0	15.0	15.0
Total External Subcontracts and Procurement	144.7	125.0	125.0	125.0

Table S4.6 Procurement from Small or Disadvantaged Businesses ($ in millions)

Source	FY 1999	FY 2000	FY 2001	FY 2002
Procurements from Small or Disadvantaged Businesses	65.1	55.0	56.0	56.0
Percent of Annual Procurement	55.4	54.2	54.2	54.2