Argonne National Laboratory

INSTITUTIONAL PLAN

FY 1997 – 2002

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October 1996

This October 1996 *Institutional Plan* was originally prepared in the spring of 1996. It generally describes the activities and plans of Argonne National Laboratory as of that time. Thus, for example, financial data for FY 1996 are mid-year projections. In addition, a few selected revisions to the *Draft Institutional Plan* of May 1996 are included to reflect comments received and major shifts in plans.

Contents

I. Laboratory Director's Statement

The *Institutional Plan* is the culmination of Argonne's annual planning cycle. The document outlines what we regard as the optimal development of programs and resources in the context of national research and development needs, the missions of the Department of Energy and Argonne National Laboratory, and pertinent resource constraints. It is the product of our internal planning process and extensive discussions with DOE managers.

As Argonne's new director — I began work on July 15, 1996 — one of my first priorities was to begin reshaping the Laboratory's planning processes to conform to my management philosophy and to help in coping with an increasingly stringent funding environment. Strategic planning is important for all of Argonne's programs, and coordination of planning for the entire institution is crucial. Our *Institutional Plan* will increasingly reflect the planning initiatives that we have recently begun.

Fifty Years of Accomplishment

I was pleased to help Argonne celebrate the 50th anniversary of its founding. The Laboratory is justifiably proud of its accomplishments over the past half century. Some highlights of Argonne's history include development of the pressurized-water and boiling-water fission reactor concepts now used in commercial reactors worldwide; development of the shell model of the atomic nucleus by Maria Goeppert Mayer, for which she shared a Nobel Prize in 1963; construction and operation of major research facilities — the Zero Gradient Synchrotron, the Intense Pulsed Neutron Source, and the Argonne Tandem-Linac Accelerator System — that pioneered accelerator and detector technology and enabled important discoveries in the physical sciences; and a host of scientific and technological innovations in such areas as electric batteries and fuel cells, low- and high-temperature superconductivity, computational science, separations chemistry, and environmental site remediation.

Our 50th anniversary celebration served to strengthen ties with many of the Laboratory's stakeholders. Events included a highly successful Business and Industry Day that drew over 300 business and government leaders, a 21st Century research symposium that included a number of Nobel laureates, a year-long Director's Special Colloquium series featuring world-renowned leaders in science and industry, an Education Day that crowded Argonne with Chicago-area students enjoying tours and demonstrations, a Laboratory Open House that attracted more than 22,000 visitors, and the kick-off meeting of a Community Leaders' Round Table organized to enhance Argonne's links with its neighbors.

Current Programs and New Initiatives

The Advanced Photon Source (APS) was dedicated on May 1, 1996. This remarkable facility, the largest user facility ever built at Argonne, will provide extremely intense X-ray beams for research over an extraordinary range of science and technology. The project management team is to be congratulated for bringing the APS into operation within budget and ahead of schedule.

Significant APS milestones during 1996 included the delivery in January of synchrotron radiation to the DuPont-Northwestern University-Dow collaborative access team, the first external user group to receive X-rays from the APS; the switching in July from electrons to positrons for regular operations of the storage ring; and, by the end of the fiscal year, the commissioning of a total of 26 experimental stations on 16 beamlines.

During commissioning of the Structural Biology Center (SBC) at the APS, early data

collected on the SBC beamline led to the solution of the tertiary structure of a potential human tumor suppressor. The finding is expected to help solve the structure of inosine monophosphate dehydrogenase, a target enzyme for drugs against autoimmune diseases and cancer. More generally, crystallographers at the SBC have begun systematic studies of the structures and functions of viruses and biological macromolecules, including enzymes and other proteins.

The centerpiece of Argonne's nuclear technology program is the Fuel Conditioning Facility (FCF) at our Idaho site. In June we started a full-scale demonstration of the electrometallurgical treatment process, using spent fuel from Argonne's Experimental Breeder Reactor-II. We were able to start operations only after a detailed environmental assessment, a lengthy public review, and the defeat of a lawsuit brought by antinuclear groups. The process technology being developed at the FCF can potentially be used to prepare for long-term storage more than 90% of the 3,000 tons of spent fuel that DOE has accumulated during 40 years of reactor operations.

Argonne chemists, in collaboration with researchers from the University of Tennessee, have developed a new high-performance chelating ion exchange resin that can be used to treat low-level radioactive waste from nuclear power plants and to extract alpha-emitting radioisotopes from mixed waste. However, its biggest use by far will be nonnuclear: to reduce iron concentrations in copper sulfate electrowinning solutions. Annual sales by an Argonne spin-off company, already in the millions of dollars annually, are expected to continue to grow rapidly.

At the Intense Pulsed Neutron Source (IPNS), we have doubled annual operating time thanks to a budget increase received through DOE's Scientific Facilities Initiative. Complementing the greater user access, we are planning significant improvements in instruments at the IPNS, including detectors, electronics, data acquisition systems, and high-speed choppers. IPNS scientists are also supporting the national effort to plan instrumentation for the National Spallation Neutron Source at Oak Ridge National Laboratory.

In a major Laboratory initiative at the Argonne Tandem-Linac Accelerator System (ATLAS), we are conducting R&D to extend heavy-ion research at ATLAS to radioactive (unstable) beams. As described in this *Plan*, the new Exotic Beam Facility will open exciting opportunities for understanding fundamental nuclear processes during and shortly after the Big Bang, for testing predictions of our most fundamental models of matter and energy, and for measuring the properties of atomic nuclei far from stability, at their very limits of existence. The DOE-National Science Foundation Nuclear Science Advisory Committee has given a radioactive beam facility the highest priority among major construction projects for nuclear physics.

Argonne is preparing a major initiative in computational science applications. Under this initiative, we will (1) establish a major new computing facility supporting computational science and integrated collaborative research and (2) conduct R&D to build, integrate, and use the core technology for distributed collaborative science and technology. To support development of this initiative, the Laboratory has prepared and submitted a strong set of proposals to DOE's Grand Challenge Applications Competition.

Argonne believes that the initiatives presented in this *Plan* represent important opportunities to advance scientific understanding and engineering achievement. The 11 "Laboratory initiatives," ranging from computational science applications to international cooperation in nuclear safety and nonproliferation, have the scale and depth to significantly enhance U.S. research capabilities in their particular research areas. The 9 initiatives designated "programmatic initiatives" are more closely related to research within a single Laboratory program area. Although individually they require a smaller commitment of resources than Laboratory initiatives, each programmatic initiative pushes at the frontier of technical knowledge. All of Argonne's initiatives are based on the accomplishments and core competencies of the Laboratory.

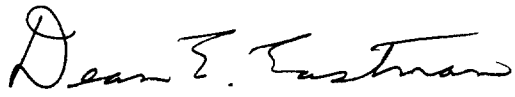
Performance-Based Vision

I am a firm believer in the usefulness of articulating a vision for Argonne, as a starting point for maximizing the Laboratory's service to DOE and the nation, especially when resources available for R&D are severely constrained. We must understand both what we want to accomplish and the nature of the strategies most likely to yield success. In broadest terms, our vision for Argonne is to enhance the Laboratory's standing as a world-class provider of science, technology, and service products, achieving excellence in satisfaction among our customers and stakeholders.

Key elements of Argonne's vision are achievement of leadership in responsiveness and efficiency ("time-to-market/cycle time") and achievement of trust as a resource, a supplier, and a neighbor. Among strategic approaches to that vision, the most basic is an unceasing focus on understanding customers and stakeholders. Also necessary are a workforce optimized for creativity and productivity, a pervasive dedication to continuous improvement, and management based on objective measurement of performance.

Conclusion

This is my first *Institutional Plan* and my first "Laboratory Director's Statement." With fresh eyes, I see a Laboratory well positioned to evolve and cope with a rapidly changing national and global R&D environment. Argonne today has the people and the tools needed to undertake the job ahead. It is only appropriate that I begin my tenure by thanking my predecessors, from Enrico Fermi and Walter Zinn to Alan Schriesheim. Their legacies will always remain a fundamental part of Argonne National Laboratory.



Dean E. Eastman

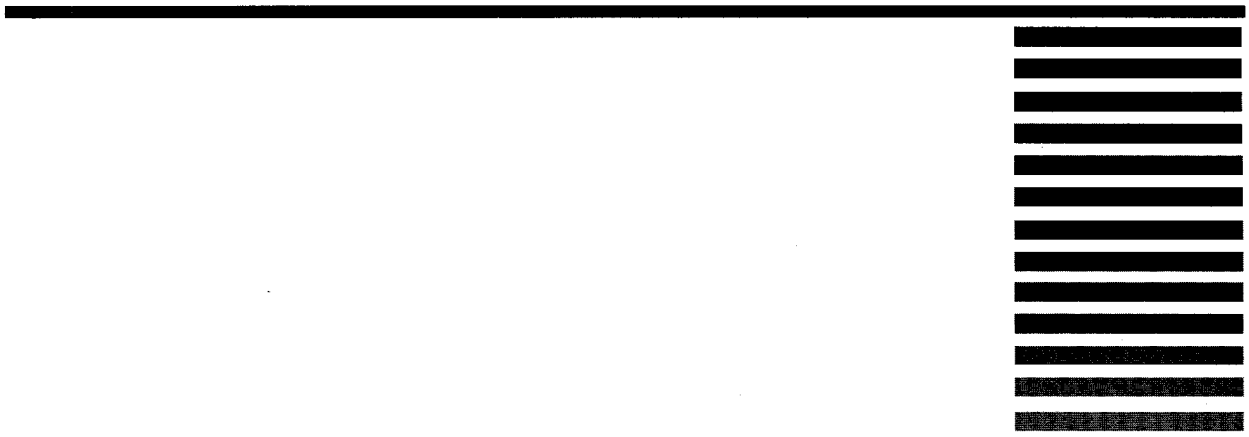
Strategic View

The chapters of Argonne's *Institutional Plan* are grouped under major headings that emphasize the relationship of the chapters to strategic planning by the U.S. Department of Energy. The chapters in this initial group — Strategic View — describe the Laboratory's

- Missions and Core Competencies (Chapter II) and
- Strategic Plan (Chapter III).

Chapter groupings that follow are titled

- Serving DOE Mission Priorities (Chapters IV-VI),
- Critical Success Factors (Chapters VII-XI), and
- Resources (Chapter XII).



II. Missions and Core Competencies

Argonne National Laboratory is a large multiprogram 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 energy technology, environmental quality, scientific leadership, and educational infrastructure. To accomplish its mission for the Department and the nation, Argonne strives continually to improve its leading-edge capabilities in science and engineering, with emphasis on its recognized core competencies.

A. Mission Areas

Argonne's major mission areas are the following:

- *Fundamental Science*

Experimental and theoretical work in the physical, life, 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, 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 is the world's most brilliant source of X-rays for forefront research in technology and science.

- *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 Partnership for a New Generation of Vehicles and the Industries of the Future initiatives; advanced batteries and fuel cells; high- and low-temperature superconducting materials and their applications; and advanced fossil fuel conversion technology.

- *Environmental Technologies*

Technology for nuclear waste management, nuclear decontamination and decommissioning (D&D), industrial waste management, and site 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*

Arms control and nonproliferation technologies. Areas of emphasis are reduced-enrichment fuel for research reactors throughout the world and systems for materials control and accountancy.

- *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.

- *Education*

  Enhancement of 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. The ARCH Development Corporation licenses technology and, where appropriate, organizes new firms.

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.

The Laboratory conducts work for each of DOE's program secretarial offices. A large portion of its work is, however, concentrated in two areas: *basic energy sciences*, where the Advanced Photon Source and associated facilities are prominent, and *nuclear technology*. Basic energy sciences and nuclear technology constituted roughly half of all Argonne research in 1996.

Argonne applies its special capabilities to perform research for federal agencies other than DOE, for nonfederal government agencies, and for private industry. (Section V.C explains how this "work for others" is managed for consistency with other elements of the Laboratory's mission.)

B. Core Competencies Based in Science and Technology

Through 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 effectively perform its missions for the Department of Energy 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 distinguishes itself by the following broadly applicable 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, integrated research programs in materials sciences, chemical sciences, and mechanistic biology

- 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, development, assessment, and remediation
- 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

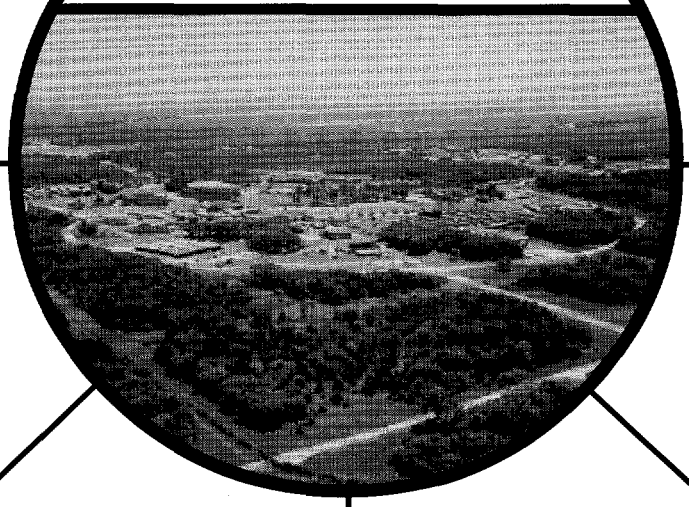
The following foldout chart describes the scientific and technological capabilities underlying these eight core competencies.

Argonne National Laboratory

CORE COMPETENCIES
BASED IN SCIENCE AND TECHNOLOGY

Argonne National Laboratory

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
- Conducting Large-Scale, Integrated Research Programs in Materials Sciences, Chemical Sciences, and Mechanistic Biology
- Assessing, Developing, and Testing Energy-Efficient Industrial, Transportation, and Other End Use Technologies
- Application of Modeling, Simulation, and Advanced Computing and Communications to Study Complex Systems and Phenomena
- Integration of Environmental Research, Development, Assessment, and Remediation
- Planning and Implementing R&D Partnerships with Industry and Universities to Address Problems in Primary Mission Areas
- Educating and Training Future Scientists and Engineers by Using Frontier Research Techniques and Facilities

SCIENCES

Materials Sciences
- Superconductivity
- Magnetic Materials
- Surface and Interface Studies
- Radiation Effects
- Neutron and X-ray Diffraction and Scattering
- Analytical and Transmission Electron Microscopy
- Laser Resonance Spectroscopy
- Thin-Film Materials

Chemical Sciences
- Photosynthesis
- Coal Science
- Heavy-Element Separation Science
- Electron- and Photon-Stimulated Fast Chemistry
- Theoretical Chemical Dynamics
- Cluster Chemistry

Biosciences
- Computational Biology
- Structural, Cellular, and Molecular Biology
- Genome Sequencing
- Bioprocessing
- Ecology

Synchrotron Radiation Techniques
- Biostructure Determination
- Time-Dependent Materials Characterization
- Lithography
- Atomic Physics and Surface Science
- Advanced X-ray Optical and Detection Techniques
- Synchrotron Radiation Sources

Mathematics and Computer Science
- Linear Algebra and Optimization
- Automated Reasoning
- Codes for Massively Parallel Architectures
- Algorithms for Computational Science and Engineering
- Modeling, Simulation, and Visualization for Energy and Industrial Technologies

Information Sciences
- Information Retrieval
- Advanced Communication Technologies
- Database Management

Accelerator Physics and Technology
- Accelerator Systems and Design
- RF Superconducting Technology
- Advanced Particle and Photon Detectors
- Magnetic Field Measurement and Analysis
- RF and High-Voltage Power Systems

High Energy and Nuclear Physics
- Particle Physics
- Heavy-Ion Physics

National Research Facilities
- Advanced Photon Source
- Intense Pulsed Neutron Source
- Argonne Tandem Linear Accelerator System
- High-Voltage Electron Microscope Facility
- Hot Fuel Examination Facility
- Experimental Breeder Reactor II
- Transient Reactor Test Facility
- Fuel Cycle Facility
- Alpha-Gamma Hot Cell Facility
- Structural Biology Center
- High-Performance Computing Facility

TECHNOLOGIES

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

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

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
- Pyro- 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
- Ultra-High Vacuum Science and Technology

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

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 Science and Technology
- Environmental Control Technology
- Nuclear Waste Management
- Rapid Site Characterization
- Land Reclamation
- Environmental Pathways Modeling and Measurement
- Natural Resource Impacts: Evaluation and Remediation
- Atmospheric Sciences and Climate Change Modeling
- Inorganic and Isotopic Geochemistry
- Analytic Geographic Information Systems
- Health Risk Assessment

III. Strategic Plan

This chapter presents an overview of Argonne's strategic planning. It articulates the Laboratory's vision for the future and describes how Argonne's major initiatives support the Laboratory's strategic goals and the primary missions of the Department of Energy. For 18 Laboratory program areas, it 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 is updated frequently, as required by new developments, including shifts in federal R&D priorities and changes in federal budgets.

A. External Environment

The most globally and immediately pertinent issue affecting fulfillment of the Laboratory's strategic plans is its success in obtaining funding for major initiatives and key ongoing programs. Major drives for budget reductions by the administration and Congress limit support for initiatives and programs. Resulting funding reductions can be only partially offset by cost reductions from streamlining and improvements in efficiency.

In the executive branch,

- As part of the National Performance Review, DOE is preparing the Secretary's Performance Agreement with the President for FY 1998, which will be consistent with the Department's strategic plan and annual performance plan and with congressional appropriations;
- DOE's strategic alignment and downsizing initiative is developing a path toward $14.1 billion in budget reductions over five years, including $5.6 billion in program reductions and $1.8 billion in savings from contractors' operations;
- The Galvin Task Force, commissioned by DOE as the first independent post-Cold War review of the Department's ten national laboratories, affirmed the Department's traditional core missions but recommended radical simplification of the Department's oversight of laboratory operations in order to reduce costs;
- The Yergin Task Force affirmed the importance of continuing most of the Department's applied energy R&D programs and provided tools for setting R&D priorities to guide the cutting of $1.2 billion from these programs over five years; and
- The draft *Strategic Laboratory Missions Plan* of the Laboratory Operations Board — a pathbreakingly detailed description of DOE's R&D mission elements and how they are carried out in concert by the Department's laboratories along with academia and industry — explained the management principles that the Department uses to maximize the overall cost-effectiveness of its R&D programs.

In Congress,

- Deficit reduction, targeting a balanced federal budget by 2002, has become an overriding legislative and presidential priority; and
- The federal role in civilian technology R&D, particularly research partnerships between the national laboratories and private industry, is being severely questioned.

These developments and others are presenting the Department and its laboratories with unprecedented uncertainties. Argonne will use the plans and projections presented in this *Institutional Plan* as a baseline for adjusting to

actions in the Congress and DOE and to other future developments.

B. The Argonne Vision

Argonne's vision is to serve as a premier multiprogram laboratory of the Department of Energy, distinguished by unique research programs and facilities and working in partnership with industry and academia to provide the nation with maximum value for its investment.

The Laboratory's largest user facility, the Advanced Photon Source (APS), will begin operations in 1996, promising scientific discoveries and technological advances in materials, biological systems, and other areas. Researchers with a wide range of industrial and academic interests will also use other unique Laboratory facilities, including the Intense Pulsed Neutron Source (IPNS), the High-Performance Computing Research Facility, the Argonne Tandem-Linac Accelerator System (ATLAS), and the Electrochemical Analysis and Diagnostics Laboratory. From both user and sponsor perspectives, Argonne will be the location of choice for important national research facilities.

Through its nuclear energy programs, the Laboratory will play a central role in meeting national priorities in nonproliferation, nuclear reactor safety, and disposition of spent fuel. The Laboratory will be recognized for its leadership in developing productive energy R&D partnerships with industry and for innovative advances in energy-efficient transportation and industrial technologies, fossil energy systems, and environmental technology.

In addition to its primary role in support of DOE, Argonne will be a major R&D resource for other public agencies and a focal point for research in the Midwest. The Laboratory will be recognized as a valuable source of innovations and a productive collaborator for industry.

The Laboratory's staff will include leading scientists and will provide uniquely valuable research, education, and training opportunities for students and faculty.

Argonne's productivity will depend fundamentally on its employees' initiative and inspiration, supported by intelligent organization, wise management, appropriate facilities and equipment, and rationalized oversight by the Department of Energy. In both its science and engineering and its administrative functions, the Laboratory will fully exploit advanced systems for computing, communications, and information distribution. Management and staff will be dedicated to continuous improvement in the quality and efficiency of research programs and products.

Argonne will remain firmly committed to excellence in protecting the environment and the health and safety of workers and the public. The Laboratory will be a trusted neighbor in its local community, as well as a valuable resource for the economies of Illinois and the Midwest.

C. Strategic Objectives by DOE Mission Area

Since 1986, Argonne has organized the strategic plan in its *Institutional Plan* under categories that DOE has recognized as its primary mission areas: science and technology, energy resources, environmental quality, and national security. In addition, Argonne has recognized the importance of the Department's derived mission to enhance the nation's economic productivity on the basis of work in its four primary mission areas. For each mission area, this section provides a general statement of Argonne's overall R&D goal, followed by a brief description of specific programmatic objectives and the programs and initiatives that the Laboratory is pursuing in the area. Larger initiatives are described more fully in Chapter IV; existing programs and other initiatives are described in Chapter V. Cross-cutting perspectives are provided in the R&D area plans in Section III.D.

1. Science and Technology

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 enrich science and mathematics education in the United States.

Supporting and Basic Research

- Strengthen Laboratory capabilities for materials synthesis and processing, including primary synthesis procedures applicable to many kinds of materials.
- Develop the innovative technique of DNA sequencing by hybridization on oligonucleotide chips, focusing on automation, biochemistry, mechanical processing, and computing.
- Conduct research to establish the fundamental physics of high-temperature superconductors.
- Exploit the Laboratory's multifaceted capabilities for chemical synthesis in a program to prepare new types of compounds, catalysts, and extractants for use in energy production and environmental control processes.
- Develop algorithms and tools for advanced computer architectures, particularly for parallel systems, and apply these capabilities in areas such as global climate modeling, computational chemistry, materials science, and computational biology.
- Develop advanced detector systems for use at high energy physics accelerators. Develop and test advanced concepts and experimental equipment for particle acceleration, such as the Demonstration Wakefield Accelerator.

Major Research Facilities

- Begin operation of the APS, a superintense source of high-energy X-rays, and improve operational parameters to meet the current and future requirements of a very large and diverse community of users. Develop insertion devices, beamline instrumentation, X-ray detector systems, and experimental facilities.
- 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 through efforts by research groups from inside and outside the Laboratory.
- Operate laboratories in computing and communications to explore integration of multimedia technology with scientific supercomputing, virtual environments for scientific visualization, and advanced communications technologies based on high-performance networks.
- Continue conducting R&D in support of accelerators, targets, moderators, and instruments for advanced neutron sources. Study a 5-MW option for a new source. Develop and upgrade the instrumentation and data analysis systems of the IPNS to support continued operation of a world-class facility.
- Develop a facility to accelerate beams of unstable nuclei, capitalizing on the capabilities of the Laboratory's existing heavy-ion accelerator, ATLAS, by using it as the postaccelerator in a two-accelerator design.
- Develop advanced instrumentation and techniques for analytical, high-resolution, and high-voltage electron microscopy, and support a broadly based electron microscopy center that is oriented toward collaborative research.

Education

- Continue to develop innovative programs to support and enhance U.S. mathematics and science education, with emphasis on college faculty and students and on involvement of women and minorities.

2. Energy Resources

GOAL: To develop, test, and carry to proof of concept technologies that can substantially improve the safety and reduce the costs of fission energy systems; to conduct base technology research to understand and remove barriers to the development of other advanced energy technologies.

Nuclear Technology

- Adapt Argonne electrometallurgical technology to condition DOE spent fuel into a standard form suitable for disposal in a geologic repository.
- Develop the International Nuclear Safety Center, with an initial focus on the safety of Soviet-designed reactors.
- Develop safe, cost-effective technologies for decontamination and decommissioning and use the CP-5 Reactor and other Argonne nuclear facilities as test beds.

Energy Efficiency

- In cooperation with the U.S. auto industry, develop cost-effective, energy-efficient technologies, focusing on electric batteries and fuel cells, advanced compression-ignited engines, 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.

Environmental and Energy Systems

- Develop technologies to improve environmental and economic consequences associated with (1) use of depletable natural resources, particularly energy resources, and (2) emissions from energy production and use at local, national, and international scales.

Renewable Energy

- Explore biochemical pathways for processing technologies to convert biomass into useful chemicals.

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.

Superconducting Technology

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

Fusion Energy

- Design, construct, and operate facilities for testing multiple interactions between thermal, mechanical, and magnetic effects in first-wall/blanket systems.

3. Environmental Quality

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 and operate a prototype user facility for atmospheric science, focused initially on the planetary boundary layer, within DOE's Cloud and Radiation Testbed site in southern Kansas.
- 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 over time the sustainability of natural resources.
- Develop a comprehensive program in the assessment and management of risk, to investigate hazards, exposure pathways, and impacts.

DOE Sites

- Help DOE implement environmental restoration and waste management activities for DOE sites; provide innovative decision tools, environmental pathway models, and environmental technologies for more cost-effective and timely approaches to waste minimization, pollution prevention, and cleanup at DOE sites.
- Integrate scientific research to develop technologies for treating (1) waste streams within DOE (e.g., high-level waste and spent nuclear fuel) and (2) other waste streams (e.g., low-level mixed waste and dense nonaqueous-phase industrial solvents); develop dual uses for these technologies.
- Support DOE programmatic initiatives by preparing environmental impact statements for major DOE facilities.

4. National Security

GOAL: To apply the Laboratory's unique technical resources to define and solve problems encountered in the development of advanced arms control, nonproliferation, verification, and defense technologies.

- Develop opportunities for cooperating with the former Soviet states and Eastern European countries to redirect R&D resources toward civilian objectives.
- Support extension of 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.

5. Economic Productivity

GOAL: To strengthen cooperative R&D, improve industrial access to Argonne facilities, and develop other associations with industry in order to exploit research in DOE's primary mission areas that can improve the productivity of U.S. industry.

Industrial Applications of X-Ray and Neutron Sources

- Exploit fully the multitude of industrial applications for the APS, including investigations of composite materials, layered surfaces, microelectronics, catalysts, medical imaging, and the structures of key biomolecules such as viruses and proteins.
- Continue to apply experimental facilities at the IPNS to industrial problems, such as those related to

polymer and zeolite structures, residual mechanical stress in welds, and petroleum geology.

Industrial User Facilities and Cooperative R&D Agreements

- Implement CRADAs (cooperative research and development agreements) and other R&D partnerships with U.S. companies to maximize the nation's economic benefits from the Laboratory's programs.
- Establish a user facility to help midwestern companies solve their materials R&D problems, through use of specialized equipment, introduction to the Laboratory's large-scale facilities, collaborative R&D, and general participation in the maturation of Argonne's materials research.

D. R&D Area Strategic Plans

As a multiprogram laboratory, Argonne takes pride in its multidisciplinary capabilities and its ability to mobilize R&D resources to address a broad range of R&D problems. At the same time, Argonne defines its strategic role in the DOE system largely in terms of the special, often unique, capabilities of its research facilities and of the research teams it can apply to nationally important R&D problems. It is such combinations of extensive skills with intensive capabilities that make each of DOE's multiprogram laboratories unique and that make the DOE laboratory system an R&D resource unmatched in the world.

Foremost among Argonne's special capabilities is the Advanced Photon Source (APS). The APS will serve an extraordinary range of scientific and technology interests, a range perhaps broader than that of any research facility yet constructed. Other Argonne facilities and programs, although smaller in scale, are critically important in nationally significant research areas. One such facility is the Intense Pulsed Neutron Source (IPNS), which, over the past decade, has arguably been the world's most reliable and cost-effective source of neutrons for materials research. Another, the Argonne Tandem-Linac Accelerator System (ATLAS), provides beams of heavy ions with precise energy and time resolution for research in nuclear structure and dynamics. A third, the Mechanistic Biology Center, comprises integrated programs in (1) cellular, molecular, and structural biology; (2) genome sequencing; and (3) computational biology. A fourth, the High-Performance Computing Research Facility, is addressing many industrial and academic research priorities through a vendor partnership with IBM.

Presented below are strategic plans for the following major Argonne scientific and technical programs:

1. National Research Facilities
   a. Advanced Photon Source
   b. Structural Biology Center
   c. Basic Energy Sciences Synchrotron Radiation Center
   d. Intense Pulsed Neutron Source
   e. Argonne Tandem-Linac Accelerator System
   f. High Voltage Electron Microscope-Tandem Accelerator
2. Supporting and Basic Research
   a. Materials Science
   b. Chemical Sciences
   c. Mathematics, Computing, and Information Sciences
   d. Mechanistic Biology
   e. Nuclear Physics
   f. High Energy Physics
3. Technology Development
   a. Energy and Industrial Technologies
   b. Nuclear Technology
   c. Fusion Power
   d. Environmental Research and Technology Development
   e. National Security
4. Educational Programs

1. National Research Facilities

a. Advanced Photon Source

Situation

Operation of the APS is prominent among Argonne's scientific endeavors. Many prestigious national committees have endorsed this X-ray source as the highest priority among the next generation of materials science research facilities, which promise to enhance U.S. competitiveness in a variety of critical technology areas. In 1996 the APS will begin operations as a national user facility serving the entire U.S. community of X-ray researchers. A similar, though lower-energy, X-ray source is operating in Europe. A third such facility now under construction in Japan is scheduled for completion in 1998.

The APS will become fully operational in 1996, after completion of a seven-year, $811 million construction project representing a major investment by the U.S. government. The resulting world-class synchrotron radiation research center will provide high-brilliance X-ray beams for a broad range of research from the materials sciences to structural biology and beyond. Collaborative access teams including researchers from private industry, universities, and other research institutions, both federal and private, are formulating research programs to be carried out at the APS. Forty of the 70 X-ray beamlines available at the APS have already been allocated to collaborative access teams. Built and operated for the Department of Energy, Office of Basic Energy Sciences, the APS will be accessible to all qualified users of synchrotron radiation.

Vision

The APS will function as a reliable and preeminent source of synchrotron radiation for U.S. researchers. This research will investigate a wide variety of frontier science and technology questions of importance both nationally and internationally. Through both the APS facility's design and its mode of operations, the productivity of researchers will be maximized.

Objectives

The mission of the APS is to provide synchrotron radiation generated by insertion devices and bending magnets, along with the technical and administrative support required by facility users. Major objectives are as follows:

- To construct and operate a source of high-brilliance X-ray beams that meet the requirements of a very large and diverse user community
- To develop state-of-the-art research facilities for collaborators from across the United States
- To maximize the efficiency of researchers using the APS, beginning with facility planning and design

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

Issues and Strategies

The conventional buildings required for effective operation of the APS facility have been completed on schedule. The central laboratory-office building was occupied in early FY 1996. Construction of six user laboratory-office modules was also completed. The project scope has been expanded to include completion of two additional modules without exceeding the total estimated cost of the APS project. This approach makes concurrent construction activities less likely to interfere with the attainment of early research goals.

Testing of the APS accelerator systems continues. The goal is to achieve a reliable operational source of high-brilliance X-rays during FY 1996. Critical to attaining this goal is the timely and successful installation of the requisite insertion devices, beamlines, detectors, and experimental facilities. Potential barriers to commissioning these facilities on schedule have included unforeseen technical problems, disruptions or delays in fabrication and installation, and inadequate safety provisions. These potential barriers are being overcome by a strategic R&D program for technical

components, which has improved safety and reduced technological risk while assuring constructibility and optimal design performance.

Full operation of the APS will require completion of instrumentation for X-ray research beamlines. Potential barriers to accomplishing this objective are (1) incomplete funding commitments by industrial and academic research partners and (2) the fate of proposals now pending before DOE and other federal agencies. The APS Beamlines initiative (see Section IV.A.3) includes funding for development of several highly advanced beamlines for research in the basic energy sciences and structural biology. This initiative is critical to Argonne's strategy for attaining the full research potential offered by the APS.

Also essential are continued development and implementation of a support infrastructure that responds to the needs of APS users. A staff of technical and administrative personnel has been carefully assembled to aid users in the construction and operation of their beamlines. An effective user organization provides input for the strategic development of the APS. Nearing completion is construction of a user residence facility on the APS site. This residence is being totally funded by the state of Illinois. Research productivity at the APS will be maximized through round-the-clock operation for nearly 300 days per year and ready access of users to their experiments. Data links will connect the user residence facility to research apparatus in the experimental hall. User laboratory-office modules around the perimeter of the experiment hall will give researchers ample space and immediate proximity to their scientific apparatus.

b. Structural Biology Center

Situation

Molecular biology and structural biology are driving a revolution in biotechnology. Knowledge about biological systems at the cellular and molecular levels is finding particularly important applications in industrial processes and medicine. Future advances will flow from further careful analyses of biological structure and function using X-ray crystallography, especially by exploiting the much higher brilliance of the X-rays to be produced at the APS.

In 1990 the Structural Biology Synchrotron Users Organization, sponsored by the National Science Foundation, issued a report calling for the establishment of new synchrotron-based resources for structural biology. Argonne's Structural Biology Center was conceived in response to this report.

Vision

The Structural Biology Center will serve as a major national user facility for macromolecular crystallography. Fitted with state-of-the-art X-ray optics, advanced electronic detectors, and sophisticated software and hardware, its two beamlines at the APS will substantially exceed the performance of any existing facility, by any quantifiable criterion — including data quality and quantity, reliability, speed of data recording and processing, and simplicity of using the instrumentation. Each year, hundreds of users will obtain high-quality data leading to the elucidation of the structure of large biological molecules such as enzymes, DNA and RNA, and bimolecular complexes.

Objectives

The general goal of the Structural Biology Center is to provide beamlines of synchrotron radiation that make more advanced frontiers accessible to structural biology. Specific objectives are as follows:

- To efficiently construct and operate a highly effective user facility
- To develop hardware, software, and supporting facilities that maximize the facility's productivity by fully exploiting the unique new capabilities available from the APS

Issues and Strategies

Initial funding for the Structural Biology Center construction project was provided by

DOE in FY 1994. Completion of construction is scheduled for FY 1997.

Planning and management for the Structural Biology Center are overseen by a principal users group, composed of 11 distinguished scientists. The design of the center's beamlines is being optimized for performance and efficiency through close cooperation with the staff of the APS.

c. Basic Energy Sciences Synchrotron Radiation Center

Situation

The capabilities of the APS will dramatically enhance research in DOE's Basic Energy Sciences programs. The Basic Energy Sciences Synchrotron Radiation Center (BESSRC) is being developed at the APS as a joint venture among three Argonne divisions (chemistry, materials science, and physics), the Laboratory's geoscience program, and Northern Illinois University. This partnership will ensure that the capabilities of the facility are used effectively. Two bending magnetic beamlines, one undulator, and an elliptical multipole wiggler will provide state-of-the-art capabilities in both traditional and frontier methods of synchrotron-based science.

Vision

The BESSRC facility will provide forefront capabilities to enable innovative research and important breakthroughs in broad areas of DOE's Basic Energy Sciences programs, including chemistry, materials science, atomic physics, and geochemistry.

Issues and Strategies

Planning and development for the BESSRC facility are well underway. Equipment and instrumentation are being assembled, and operation of the first bending magnet facility is expected by the end of FY 1996. Development of the undulator and wiggler beamlines will continue into FY 1997, leaving the final bending magnet for later development. Argonne has designed and developed monochromators that are cryogenically cooled to accommodate the high heat loads present in APS beams; this advance is expected to benefit other synchrotron facilities as well.

Forefront capabilities at the BESSRC will include the following:

- Inelastic X-ray scattering
- Real-time studies in short time domains
- *In situ* studies of chemical and physical processes
- High energy X-ray diffraction
- Photoionization and photoexcitation in atomic and molecular physics

d. Intense Pulsed Neutron Source

Situation

The IPNS is the largest and most active user facility currently operating at Argonne. Among DOE neutron sources, it has one of the largest user programs: approximately 300 experiments per year, with almost 200 scientists conducting at least one experiment. 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 will allow operations to double in coming years 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). For FY 1996, 25 weeks of operations are scheduled.

The IPNS was surpassed as the world's most powerful pulsed spallation neutron source by the British facility ISIS in 1988. Pulsed spallation neutron sources have demonstrated important scientific capabilities in recent years, and efforts are underway worldwide to construct more powerful sources.

Vision

The IPNS will function as a reliable and accessible user facility for neutron-scattering research and as a test bed for R&D on associated targets, moderators, and 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. The IPNS will develop a plan for an advanced pulsed spallation neutron source that will significantly increase U.S. capabilities for exploiting this powerful experimental technique.

Objectives

Major objectives for the IPNS are as follows:

- To operate the IPNS in a highly reliable manner, with availability exceeding 95%, and to provide effective scientific assistance to qualified users
- To develop new technologies for targets, moderators, and instrumentation that will increase the capabilities of pulsed spallation neutron sources
- To design and construct an advanced pulsed spallation neutron source that can exploit burgeoning scientific and technological opportunities

Issues and Strategies

The IPNS has been severely oversubscribed, understaffed, and underutilized. The additional $4 million in IPNS operating funds included in DOE's Scientific Facilities Initiative will allow approximately 32 weeks of operation per year with a full complement of instruments serving users. This funding is expected to become part of the base funding for the facility.

There is broad agreement in the scientific community that an advanced spallation neutron source could provide important technical and scientific opportunities. A workshop held at Argonne in May 1993 documented many of these opportunities, both in materials science and in other areas ranging from biology to engineering applications. Argonne has completed a feasibility study for an IPNS-Upgrade facility that has a beam power of 1 MW, 75 times that of the IPNS and 6 times that of ISIS. (See Section IV.A.5 for discussion of this Laboratory initiative.) On the basis of guidance from DOE, Argonne has now also studied a 400-kilowatt upgrade.

e. Argonne Tandem-Linac Accelerator System

Situation

The ATLAS is a DOE-designated national accelerator facility for research in nuclear physics that employs beams of low-energy heavy ions. The accelerator was recently upgraded to provide unique beams of all the stable elements up to the heaviest, uranium. These beams excel in both quality and intensity. ATLAS is based on a novel technology developed at Argonne employing low-frequency superconducting radio-frequency accelerator cavities. The ATLAS facility serves a broad community of about 200 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 improve its operations and develop new linear accelerator technology to provide beams of higher intensity with excellent phase space and fast timing. To optimize use of the facility, operational issues are reviewed continuously, and the facility's capabilities are enhanced. Argonne will be investigating technical and research issues relating to acceleration of

secondary radioactive beams, as a basis for proposing development of a radioactive ion beam facility based on ATLAS. (See Section IV.A.2.)

f. High Voltage Electron Microscope-Tandem Accelerator

Situation

Argonne's High Voltage Electron Microscope-Tandem Accelerator is a national user facility that provides a unique combination of electron microscopy interfaced with ion beam irradiation. No other U.S. facility can provide the same capabilities, which are important for characterizing materials. Studies conducted at the facility primarily involve (1) dynamic *in situ* analysis and (2) development of techniques for analyzing and observing microstructural changes resulting from irradiation, mechanical deformation, and gas-solid reactions of materials. A general advantage of an electron microscope operating at higher energies is that samples require less stringent preparation before testing.

Time at this national user facility is allocated through a formal proposal procedure. Heaviest usage is by researchers from universities. Other users are from Argonne programs, other national laboratories, and industry. Through support from the DOE Office of Basic Energy Sciences, the facility is made available for nonproprietary research at no charge to users.

Vision

Argonne will operate a state-of-the-art facility combining electron microscopy with ion beam irradiation to enable research providing important new insights into processes having major technological implications, such as radiation effects in high-temperature superconductors, radiation-induced segregation and phase transformation, hydrogen embrittlement, and solid state amorphization reactions.

Issues and Strategies

The present electron microscope has aged to the point where its replacement must be considered if the facility is to continue providing high-quality service to its users. Because modern high-voltage electron microscopes are costly, Argonne is approaching modernization of the facility with both a near-term and a longer-term strategy.

In FY 1995, an intermediate-voltage electron microscope was added to the facility without disturbing the existing high-voltage microscope. Both microscopes are interfaced with existing ion beams. Although it does not have the advantage of high-energy electrons, the new microscope provides spatial resolution substantially higher than that available from the much older microscope. This improved capability will be very useful for both outside users and Argonne researchers for many years, even if the high-voltage microscope were to become unusable.

For the longer term, Argonne is developing plans for full replacement of the existing high-voltage microscope. The replacement instrument will have substantially greater capabilities, including higher spatial resolution and much greater possibilities for *in situ* experimentation.

2. Supporting and Basic Research

a. Materials Science

Situation

Advanced materials have been identified as critical technologies in every comprehensive study of materials science conducted in recent years. New materials technologies offer important benefits across a nearly universal spectrum of applications, including the major technological priorities in DOE's core business lines.

Argonne's work on materials includes important experimental and theoretical studies that are distinguished by the integrated application of multiple scientific disciplines and

specialized facilities. The large strategic research programs conducted by the Laboratory would typically not be feasible at a university or private firm.

Argonne establishes and maintains unique materials research facilities for outside users and regularly designs and develops more capable instruments for these facilities. (See, in particular, the preceding discussions of the APS, the IPNS, and the High Voltage Electron Microscope- Tandem Accelerator.) Laboratory researchers frequently work closely with colleagues at industrial corporations and universities. Work with industry often aims at developing for commercial applications new materials discovered in Argonne's basic research program.

Significant Laboratory programs are addressing superconductivity, radiation effects, surface and interface phenomena, and magnetic materials. Argonne's contributions to the fundamental understanding of materials' properties and the development of new materials continue to be well recognized internationally.

Vision

Argonne will foster world-class science, forefront instrumentation, and unique user facilities enabling cutting-edge materials research that provides the knowledge and technology needed for DOE and the nation to achieve their scientific and technical goals. This work will include the development of new materials and the characterization of materials' properties, both built on improved understanding of the underlying fundamental science.

Objectives

Specific objectives of Argonne's research on materials include the following:

- To develop and apply innovative techniques that exploit the unique capabilities of the APS and the IPNS
- To establish the fundamental physics of high-temperature superconductors and develop valuable new applications of such materials
- To develop and characterize new magnetic materials suitable for permanent magnets and other applications
- To improve the interface and surface properties of materials, particularly to benefit materials processing, catalytic action, and environmental effects
- To develop and apply new techniques for electron beam microcharacterization that provide improved analytical methods at greater spatial resolution
- To establish an integrated understanding of modifications of materials resulting from irradiation with electrons, ions, and neutrons and to develop means of mitigating radiation damage

Issues and Strategies

Primary issues are (1) maintaining funding from the DOE Office of Basic Energy Sciences and (2) supporting DOE's technological mission goals more broadly and directly.

To meet these challenges, more effective ties to applied materials programs and other relevant R&D programs throughout the Laboratory continue to be established. Formal mechanisms are now coordinating basic and applied work in engineered materials and related fields into integrated thrusts toward stronger partnerships in more areas.

Argonne is participating extensively in efforts to strengthen collaborations 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 sponsored by the Division of Materials Sciences of DOE's Office of Basic Energy Sciences. Argonne is involved in several thrusts aimed at integrating the development of interlaboratory programs with industrial collaborations. The Laboratory has a primary coordinating responsibility for a program to develop better permanent magnets.

Argonne's research at the APS in materials science — as well as in other physical sciences — will center on the Basic Energy Sciences Synchrotron Radiation Center.

The Laboratory's work in superconductivity benefits from close coupling with the National Science Foundation-supported Science and Technology Center for Superconductivity, a consortium including Argonne, Northwestern University, the University of Illinois, and the University of Chicago.

b. Chemical Sciences

Situation

Chemistry has been a core capability of Argonne since the Laboratory's earliest days. Today the Laboratory is conducting cutting-edge research in six distinct fields of chemistry. Results are important for advances in pollution prevention, energy efficiency, energy conversion, and industrial catalysis. Metrics such as peer reviews and citation counts consistently indicate that the Laboratory's chemists are leading contributors at the frontiers of their discipline.

Vision

Argonne will continue to make broad contributions to fundamental chemistry and basic chemical technology that will provide major economic and environmental benefits to the United States.

Objectives

Argonne's work in chemical sciences will center around the advancement of knowledge in six fields characterized by the following selected central objectives:

- To conduct seamlessly integrated research programs in the separation sciences of the heavy elements, such that resulting discoveries are readily available for use by DOE; to extend these programs to help U.S. industry prevent pollution and manage nonradioactive wastes
- To provide a basic understanding of electron and charge transport in natural and artificial photosynthesis and also in other types of photochemical energy conversion systems
- To define fundamental combustion processes, exploiting state-of-the-art experimental and computational capabilities at Argonne; to effectively transfer results to industry to enable technological advances
- To extend understanding of radiation and photochemistry, aiming especially at identifying the fundamentals of electron transfer and hydrogen atom transfer that will undergird the development of technologies that are more energy efficient
- To pioneer fundamental understanding of the structure and behavior of coal, petroleum, and other fossil energy sources; to work in partnership with U.S. industry to make exploitation of these resources increasingly efficient and environmentally sound
- To elaborate the chemistry of metallic clusters and other novel catalysts to improve chemical processes

Beyond the central objectives of maintaining the productivity and preeminence of its work in the six areas indicated above, the Laboratory aims to undertake extensive experimental research at the APS, using synchrotron radiation with time-resolved X-ray absorption spectroscopy to study transient molecular structures in photochemical reactions, especially reactions that are important in solar energy conversion. In addition, the Laboratory plans to develop a user facility for synchrotron research on the molecular and environmental science of actinides. A particular objective is to reduce problems associated with handling radioactive materials safely at synchrotrons. Also planned is construction of an X-ray scattering instrument at the APS on the undulator beamline of the Basic Energy Sciences Synchrotron Radiation Center, to create unprecedented opportunities for

studying static and dynamic order in condensed phases and nanoscale materials. The APS also creates opportunities to study atomic physics with hard X-rays in an energy regime where the fundamental photon-atom interaction has not yet been explored.

Issues and Strategies

Opportunities for leading-edge research in chemical sciences at Argonne will be enhanced in exciting ways by the APS. Exploiting X-ray time domains never previously accessible, this third-generation synchrotron X-ray source will greatly increase researchers' power to define the structures of transient substances ranging from photoexcited states, to complex metal clusters, to heavy-metal complexes created electrochemically. Argonne's chemists have prepared for these opportunities during the construction of the APS by creating new research teams and working steadily to surmount a succession of technical barriers, though these high-priority efforts have been significantly constrained by the availability of resources. As the capabilities of the APS create new opportunities for frontier research in the chemical sciences, Argonne will continue to formulate creative proposals — such as those identified above — to seize the opportunities.

Argonne has unusually rich opportunities for fruitful partnership with the chemical industry through contributions to the chemistry of pollution prevention. The Laboratory has particular strength in the separations sciences for the heavy elements, which has enabled the development of technologies for cleaning up radioactive waste at the Hanford Reservation. The next goal is parallel research aimed at developing similarly powerful technologies for managing the nonnuclear wastes generated by many other U.S. industries.

c. Mathematics, Computing, and Information Sciences

Situation

Computers are becoming increasingly fundamental to the advancement of science and engineering, complementing and, in some cases, substituting for conventional methods of theory and experiment. In the future, the most cost-effective way of exploiting the full power of computers — which often are distributed in various sites across the nation — will be to link them via high-speed networks.

An important milestone in Argonne's program in high-performance computing and communications was its acquisition of a state-of-the-art massively parallel IBM SP computer system. Recently, Argonne linked the SP to its Cave Automated Virtual Environment (CAVE), enabling researchers to simulate multi-dimensional phenomena in real time. With collaborators from industry, universities, and other national laboratories, Argonne researchers are developing the parallel algorithms, software tools, and visualization technologies needed to make such new capabilities truly effective scientific resources.

Argonne has an extensive program to apply the latest advances in computer technology to decision systems and to the development and testing of improved information management systems. This work emphasizes the application of emerging technologies — such as artificial intelligence, heuristic systems, and object-oriented databases — to management problems of the federal government and U.S. industry that can benefit from advances in information systems and decision-making procedures. Working in partnership with other national laboratories, with universities, and with industry, the Laboratory strives to bring these emerging tools into wider use through design prototyping and testing in real applications that stress system capacities.

Argonne also took a principal role in the Information Wide Area Year (I-WAY) project — an experimental high-speed network supporting the sharing of remote computing resources. The Laboratory led two critical components of the I-WAY: (1) assembling the advanced network and (2) developing the software that enables different machines to communicate and share work.

The recently proposed DOE2000 initiative promises further challenges and opportunities

for Argonne's programs in computing and communications.

Vision

Argonne will make seminal contributions to the next generation of software, systems, and algorithms for DOE scientific computing applications. In response to the new federal emphasis on linking massively parallel computers and other scientific resources over advanced networks, Argonne will pursue a vigorous R&D program to explore high-end telecommunicating, next-generation Internet technology, and virtual environments. In addition, the Laboratory will build software and input-output environments to support computing at teraflops speeds. Argonne will also apply and improve the most advanced concepts of information science to serve planners and decision makers in the federal government and U.S industry.

Objectives

Central objectives of Argonne's programs in computing and information sciences are as follows:

- To pioneer the study of advanced networking technology, including security mechanisms for wide-area computing and network management
- To make critical contributions to the software and input-output environments needed for effective computing at petaflops speeds in an interactive environment
- To provide leading-edge enabling technology for managing multi-dimensional data, remote access to user facilities, and high-performance internetworked computation
- To explore the close coupling of immersive virtual environments, super-computing, and multimedia technology, in order to solve major scientific and industrial problems

Issues and Strategies

Argonne is responding quickly to the growing federal emphasis on large-scale parallel computers and national networks. An important step is the Laboratory's initiative to establish a Center for Collaborative Science and Technology. (See Section IV.A.1 for further discussion of this initiative.)

Major new computer science technology will be needed for integrating scientific super-computing techniques into a coherent body of tools and methods that will work effectively over high-speed networks. Argonne computer scientists are working on scalable input-output environments that can serve machines operating at teraflops speeds. They are also playing a lead role in implementing a standard message-passing interface and in developing software tools to provide a uniform environment among different and remote computer architectures. Cooperative partnerships with vendors and national service providers, as well as potential scientific users of these tools, will be required to ensure their widespread acceptance and maximum national benefits.

The federal government's DOE2000 initiative is expected to give high priority to novel computational tools and libraries that advance the concept of virtual laboratories. In response, Argonne is increasing its commitment to projects such as LabSpace, a social virtual reality environment through which scientists can share remote facilities in virtual space. In addition, the Laboratory is exploring novel techniques for CAVE-to-CAVE experiments and an integrated media server that provides network-based video and audio services for collaborative work environments.

d. Mechanistic Biology

Situation

Biological research traditionally has focused on identifying the components and pathways involved in the metabolism of living organisms. The limitations in that type of knowledge increasingly indicate that future study should move toward investigating the mechanisms by

which the components of the pathways act and interact. That is, biological research should shift from a phenomenological focus toward one that is mechanistic. Modern biology — cellular, molecular, structural, and computational — today has tools capable of revealing the fundamental molecular mechanisms governing phenomena such as cell replication, differentiation, mutagenesis, and carcinogenesis. Applications of this new understanding promise the prevention and cure of diseases, more efficient environmental restoration, and improved industrial processes based on new biotechnologies.

Vision

Argonne will carry out a synergistic program of research on cells, nucleic acids, and proteins that will increase our ability to understand the fundamental mechanisms of life and to implement valuable applications such as injury prevention, disease therapies, environmental restoration, and improved industrial processes.

Objectives

Argonne's work in mechanistic biology is at the cutting edge of new developments in cellular, molecular, structural, and computational biology. By bringing together branches of biology that are traditionally separate and by exploiting state-of-the-art computation, the Laboratory plans a program of research that is highly integrated and mutually reinforcing. This research will range from fundamental studies of DNA sequences to practical applications, such as protein engineering suitable for transfer to private industry for commercialization.

Major Argonne objectives are as follows:

- To continue developing the technique of sequencing by hybridization as a tool for more efficiently unraveling genomic DNA sequences
- To develop the analytical approaches and software required to exploit massively parallel computers for exploring the three-dimensional structure of proteins
- To study hyperthermophilic organisms in order to learn how proteins can function at environmental extremes
- To exploit the unique capabilities of the Structural Biology Center at the APS to explore questions of reaction mechanisms and molecular structure that are currently intractable

Issues and Strategies

Sequencing the human genome by using traditional gel-based methods would require an inordinate amount of time and effort. Argonne is developing an alternative approach, sequencing by hybridization on oligonucleotide microchips, which can increase the speed and efficiency of DNA sequencing by orders of magnitude, largely because it reads "phrases" of DNA rather than individual "letters," and because it can be highly automated. (See Section IV.A.4.)

Determining the three-dimensional structure of a protein today requires application of X-ray crystallography to individual protein crystals, a technique that is time- and labor-intensive. Argonne's Computational Biology program aims at using state-of-the-art massively parallel computers to develop the capability to solve the structure of proteins solely from knowledge of the DNA coding sequence. This capability promises to significantly enhance the engineering of proteins to serve specific industrial and medical purposes. (See Sections IV.A.1 and IV.A.4.)

Almost all enzyme reactions are limited to the relatively mild conditions in which normal organisms live. Conditions even slightly harsher can render normal enzymes inactive. However, the organisms known as hyperthermophiles produce enzymes that are stable and active at extremes of temperature, pH, osmotic pressure, and solvent environment. Argonne is beginning to study these rare organisms, aiming ultimately to understand how broader classes of proteins can be modified to function under extreme conditions. The resulting new biotechnologies

could have high value in applications such as industrial processes and environmental remediation.

The Structural Biology Center at the APS will provide resources allowing effective approaches to difficult biochemistry problems that cannot be solved by conventional means today, including the elucidation of structure-function relationships in macromolecules, the study of intermediates in molecular processes and reactions, and improving the ability to take X-ray data from crystals of macromolecules. Representative molecules for which the Center's capabilities will be particularly valuable include chaperone proteins, cytochromes, immunoglobulins, and cancer suppressor genes. (More detailed plans for the Structural Biology Center are presented in Section III.D.1.b.)

e. 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 ATLAS facility (discussed in Section III.D.1.e); (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 nuclear dynamics and subnucleonic particles in the nucleus.

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 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 of their stability, at high excitation energies, in exotic shapes, and at rapid rotation. Producing and detecting previously unknown isotopes and studying their structures can benefit greatly from secondary (radioactive) beams, which can make accessible regions of nuclei not currently reachable with stable beams. To this end, Argonne is proposing a national Exotic Beam Facility that will be based largely on novel superconducting accelerator technology originally developed at the Laboratory and used for ATLAS. (See Section IV.A.2.)

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. To advance the state of the art of lepton-scattering studies in electron storage rings, the Laboratory is developing new technologies for internal polarized nucleon targets to be used in facilities at DESY and Novosibirsk. Laboratory researchers are playing a leading role in the research program that just began at TJNAF, including construction of a magnetic spectrometer that is the first general-purpose spectrometer employed at that new accelerator facility.

Argonne's work in nuclear theory addresses many-body problems and the dynamics of mesons and quarks in hadrons, nuclei, and nuclear matter. Using the new IBM SP system at Argonne and other forefront computing facilities, the Laboratory recently 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 future experimental programs at TJNAF and for Brookhaven's Relativistic Heavy Ion Collider, a

new national accelerator facility currently under construction.

f. 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 six 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 these 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:

- To maximize the output and impact of new physics generated from the Laboratory's experiments
- To complete the demonstration of the Argonne Wakefield Accelerator and exploit the facility for further experiments in advanced acceleration technology
- To 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. Work on the ZEUS experiment at the German DESY facility began in 1985. More recently, the Laboratory began a project that will use the Large Hadron Collider (LHC) being planned at CERN in Switzerland. Argonne researchers have established leadership roles in the ATLAS detector, one of two major detectors planned for the LHC (and unrelated to the ATLAS facility located at Argonne). The final level of participation will be determined by DOE and Congress, which will consider U.S. participation in the LHC project, based in part on negotiations with CERN management on possible cost-sharing arrangements.

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 plans for

a long-baseline study of neutrino oscillation, employing a neutrino beam from the new Fermilab main injector, have been approved by Fermilab. The "far" detector is to be underground, adjacent to the current Soudan 2 detector in Minnesota. By the year 2005, the CDF (Collider Detector at Fermilab) program will be either upgraded to enable a new emphasis on the physics of the b-quark or replaced with a specialized b-detector. 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 will be discussing possible collaborations and alliances with researchers at other institutions.

Sources of operating funding must be identified to add polarized proton-proton scattering to the experimental program to be conducted at Brookhaven's Relativistic Heavy Ion Collider (RHIC) facility. Sources of equipment funding for additions to the RHIC facility and to Brookhaven's STAR detector have, to a large extent, been identified in Japan and within DOE's Nuclear Physics program.

3. Technology Development

a. Energy and Industrial Technologies

Situation

Argonne's Energy and Industrial Technologies program encompasses the Laboratory's development work on nonnuclear energy technologies, including fossil energy, transportation, and industrial technologies. In addition, the program coordinates the Laboratory's efforts to transfer its technologies to the private sector. Responding to the administration goal of appropriately utilizing the nation's technical resources to improve the productivity of U.S. industry, Argonne is developing partnerships with industrial firms. Extensive opportunities nationally are based on the Laboratory's acknowledged leadership in advanced research and technology. The Laboratory's location in the heart of the nation's midwestern industrial base provides exceptional regional opportunities. In the past two decades, competitive pressures toward near-term efficiency and profitability have driven many U.S. companies to reduce their investments in longer-term R&D. In this environment, R&D partnerships between the national laboratories and U.S. industry have become even more critical to the economic health of the nation.

Partnerships with industry play an important role in new Laboratory programs ranging from strategic research at user facilities (such as the APS and the IPNS) to efforts aimed at broad cooperation with U.S. industrial firms, notably in five focus areas derived from Argonne's research missions: (1) materials development, (2) manufacturing technology, (3) computing, (4) transportation technology, and (5) energy and environmental technology.

In addition to developing partnerships with large companies, Argonne explores opportunities to work with small and medium-size companies. A particular concern in this effort is making Laboratory resources available with fairness of opportunity to all. Industrial demand for R&D partnerships far exceeds the resources available to the Laboratory, so Argonne has been forced to restrict commitments to opportunities most likely to add exceptional value to private efforts while they complement the Laboratory's research programs. Several cutbacks in FY 1996 funding for industrial partnerships have greatly exacerbated this problem.

Vision

As an integral part of pursuing all its missions in science and technology, Argonne develops relationships with industry to maximize the effective commercial applications and benefits to the nation from its R&D.

Objectives

To implement this vision, central Argonne objectives are

- To develop unique scientific and technological capabilities that interest

both the industrial and scientific communities;

- To establish strategic partnerships with key industrial firms in areas where applying the Laboratory's technical strengths is most likely to lead to valuable commercial successes;
- To implement effective regional outreach to industry, capitalizing on the Laboratory's central location in the Midwest; and
- To exploit the Laboratory's capabilities and core competencies to satisfy industry's precompetitive technological needs.

Issues and Strategies

In its FY 1996 appropriations, Congress severely curtailed funding explicitly available for industrial partnerships with DOE and other federal agencies. Unless this new trend is reversed, many of Argonne's industrial partnerships will end prematurely; few, if any, new starts will be possible. Only partnerships supported by direct program budgets will be feasible.

To maximize the likelihood of developing effective industrial partnerships in specific areas of technology, Argonne has developed explicit selection criteria based on the Laboratory's scientific and technical capabilities and its core competencies. Intensive coordination among the Laboratory's program managers has been implemented in the five major industrial focus areas: (1) materials, (2) manufacturing, (3) computing, (4) transportation, and (5) energy and environmental technology. In addition to identifying promising industrial partners in these areas, Argonne is seeking opportunities to include other national laboratories and universities in productive strategic collaborations.

Argonne has already established a vigorous regional outreach program whose broad goal is to help manufacturers in the region. Focused efforts aim specifically at (1) encouraging participation in the regional initiative for intelligent vehicle highway systems being developed by the Department of Transportation and (2) helping local community groups to rehabilitate inner-city buildings (making them more energy efficient) and to promote local industrial development.

The Laboratory measures the success of its industrial partnerships through their lifetimes and beyond, considering the significance and impact of the work accomplished by the partnerships, the satisfaction of industrial partners, and, ultimately, the successful commercialization of new technologies.

General issues that are relevant for many of the Laboratory's industrial partnerships are (1) improving communications with potential industrial partners, (2) achieving better coordination between DOE and other participating federal agencies, and (3) giving special consideration to smaller businesses and urban business development.

To develop productive industrial partnerships, the Laboratory must effectively *communicate to potential partners its technological and scientific capabilities and its integrated core competencies*. Argonne fully exploits conventional forums for this communication, including special-interest workshops and a newsletter. The Laboratory has also implemented on the Internet a user-friendly, easily searchable database describing Argonne programs of potential interest to industrial partners.

Development of several Argonne industrial partnership initiatives depends critically on *coordination between DOE and other federal agencies*, particularly the Department of Commerce. In addition, programmatic cooperation with the Department of Transportation and the Department of Defense is particularly important.

The federal government conducts important programs to help *small business* directly. However, DOE has not allocated substantial resources for cooperative ventures between national laboratories and small businesses. Similarly, because *community business development in cities* is a federal priority, DOE should fund national laboratories to work with local development groups on projects aimed at rehabilitating urban housing for greater energy

efficiency or at establishing new industrial employers in cities.

Argonne is undertaking important initiatives in each of its five major focus areas for industrial partnerships.

Improved *materials* are important to most technological advances and are integral to virtually all major Argonne industrial partnership initiatives. A particular interest is using new materials to improve sensors. The Laboratory is exploring ways to facilitate its interactions with industry in the area of engineered materials.

Argonne is a regional *manufacturing* technology provider as part of the Chicago Manufacturing Technology Center funded by the Department of Commerce. The Laboratory has also led the development of an electronic database designed to guide Illinois manufacturers seeking the public R&D institutions in the state best able to help them; the database also includes community colleges.

Argonne's state-of-the art computational facilities are the basis for diverse initiatives in advanced *computing*, including the modeling and simulation of industrial processes.

Argonne continues to work closely with consortia of industrial firms, DOE, and other DOE laboratories to develop major initiatives in the broad area of *energy and environmental technology*. Current efforts focus on the metals, forest products, petroleum, and chemical industries, as part of DOE's Industries of the Future initiative.

Argonne is working with DOE, the Department of Commerce, and the Department of Transportation on three major initiatives involving partnerships with U.S. *transportation* industries: (1) fuel-efficient and environmentally benign automobiles, (2) intelligent vehicle highway systems, (3) diesel technology for trucks and heavy-duty vehicles, and (4) advanced railroad technology. (See Section IV.A.7.)

b. Nuclear Technology

Situation

As a result of its broad, long-term involvement in U.S. development of advanced reactors, Argonne possesses unparalleled, unique expertise in the full range of nuclear reactor technology. Since termination of the Integral Fast Reactor (IFR) program, DOE has established a nuclear technology R&D program at Argonne that uses the Laboratory's technical capabilities and facilities to help solve nearer-term missions being given higher priority. Program areas being developed include the following:

- *Treatment of spent nuclear fuel from DOE reactors*. Electrometallurgical technology, developed under the Laboratory's earlier IFR and Actinide Recycle programs, is applied to the treatment of spent nuclear fuel currently stored at various DOE sites.

- *Reactor and fuel cycle safety*. An international reactor safety center and other activities aim at improving the safety of nuclear reactors throughout the world; the initial focus is on Soviet-designed reactors and on developing advanced safety technologies for existing and advanced light-water reactors.

- *Decontamination and decommissioning (D&D) technology*. On the basis of experience with the CP-5 Reactor, the Experimental Breeder Reactor-II (EBR-II) system, and other Laboratory facilities, Argonne aims to develop D&D technology that eventually can be applied generically to nuclear power plants and fuel cycle facilities.

Vision

Argonne will continue its role of technical leadership in nuclear technology. The Laboratory will develop innovative technologies, demonstrate them at Argonne-West facilities

and elsewhere, and ultimately apply them to the highest-priority issues facing the nuclear industry. The DOE Office of Nuclear Energy, Science and Technology will continue to be one of the primary providers of direction and support for these programs.

Objectives

The overall goal of Argonne's nuclear technology program is to maintain levels of technical expertise and knowledge sufficiently broad and deep to address a full range of national needs, to vigorously and aggressively pursue the important technical issues associated with the use of nuclear energy, both domestically and internationally, and to support the related nuclear science and technology programs of DOE.

Strategy

Argonne's nuclear technology programs are now directed toward the following new areas:

- Development of electrometallurgical technology that (1) can be successfully applied to treating EBR-II spent fuel for disposal as part of the reactor's shutdown and (2) can serve as a proven candidate technology for treating a variety of spent fuel from DOE reactors (such as the N-reactor) and other fuel types requiring treatment before disposal in a repository
- Development of the International Nuclear Safety Center and associated international R&D collaborations, in order to distribute information about nuclear safety and to develop technology to improve the safety of nuclear facilities, particularly Soviet-designed reactors
- Development of innovative, advanced technologies for D&D of reactors and other nuclear facilities and use of the CP-5 Reactor at Argonne-East as a pilot to test innovative new D&D technologies

c. Fusion Power

Situation

Fusion energy promises power from a source that is safe, economical, abundant, and environmentally acceptable. Large technological challenges remain, but significant advances continue to be made. The new U.S. strategy focuses on providing the required underlying plasma science and technology. International work on developing fusion power continues to focus on the International Thermonuclear Experimental Reactor (ITER), which is being designed to produce over 1,000 MW.

Vision

Argonne will contribute to design of the ITER and will lead the development of vanadium-based alloys and a reliable, high-performance first-wall-and-blanket system for a successful fusion power technology.

Objectives

The central goal of Argonne's work on fusion materials and blanket technology is to develop a high-performance, low-activation first-wall-and-blanket system. Specific objectives are as follows:

- To develop vanadium-based alloys as a low-activation structural material for the first-wall-and-blanket system
- To develop and test high-performance blanket systems, particularly reliable liquid metal systems constructed of low-activation materials
- To contribute to the design and development of the ITER first-wall-blanket-shield system
- To contribute to the design and construction of a high-energy (14-MeV), accelerator-based neutron source for testing candidate materials for fusion power systems

Issues and Strategies

One of the two top feasibility issues for fusion power involves recovering fusion energy at high temperatures and providing tritium self-sufficiency in a reliable blanket system. Moreover, advantages of fusion energy related to safety and the environment are key motivations for its development. From both of these perspectives, research on materials and blanket technology is critical. In the United States, the leading blanket concept is a self-cooled liquid lithium blanket with a vanadium alloy structure. Crucial for the success of this approach is development of (1) radiation-resistant, low-activation vanadium-based alloys with electrically insulating coatings in contact with the lithium and (2) an understanding of liquid metal magnetohydrodynamic effects for lithium flowing in a high magnetic field.

Argonne will continue to work on the design and development of the ITER first-wall-blanket-shield system. In the future, a high-flux, high-energy (14-MeV) neutron source is needed for further testing of materials for a demonstration fusion reactor. Argonne is a candidate for a leadership role in the joint international development of such a source and as a site for its construction.

d. Environmental Research and Technology Development

Situation

The DOE strategic planning process prioritizes the Department's core business goals and objectives. Though the prioritization is subject to revision, it is significant that pursuit of many of DOE's top business goals depends directly on the Department's environmental programs.

Argonne's environmental programs have a long history of successfully supporting both DOE and other federal agencies with major environmental R&D responsibilities. This diversity of sponsorship is necessary for the nation to maximize the returns from its investment in the Laboratory's capabilities.

Argonne has demonstrated significant core capabilities in bioprocessing and bioremediation; ecology; modeling and measuring environmental pathways; atmospheric science; quantifying and modeling emissions of greenhouse gases and assessing their impacts; technology development in support of "clean" technologies; control and remediation technologies; inorganic and isotopic geochemistry; and development of decision models for rapid, cost-effective remediation of DOE sites. This foundation creates important opportunities for further fruitful strategic expansion in the range of creative capabilities available within the Laboratory's staff. Selective strengthening of work for non-DOE sponsors will enhance capabilities available for DOE work.

The Laboratory's capabilities in environmental R&D are notable for effectively integrating the full range of basic physical and biological sciences with fields such as economics, operations research, and computer applications, in addition to more traditional capabilities in various engineering disciplines. Integrated capabilities in environmental research, technology development and deployment, assessment, and remediation applications constitute one of Argonne's eight core competencies (see Chapter II). As federal programs seeking cost-effective solutions to environmental problems become increasingly important, Laboratory researchers of recognized professional standing, using state-of-the-art instruments and facilities, will advance the frontiers of environmental science in directions that are both technically challenging and highly relevant to important national problems.

Vision

Argonne will maintain and further develop its position as an internationally recognized performer of wide-ranging multidisciplinary environmental programs, providing innovative solutions for problems of regional, national, and global significance.

Objectives

Central objectives of Argonne's environmental programs are as follows:

- To develop pragmatic numeric methodologies, based on rigorous interpretation of analytical models and original research data, to support decisions on complex environmental issues
- To continuously develop the quality staff and state-of-the-art facilities needed to conduct science and technology that effectively address key environmental issues facing DOE and the nation
- To transfer innovative knowledge, methodologies, and technologies to the private sector, where they become operational standards
- To contribute to the integrated information, assessments, and technological options needed by government officials and policymakers to establish appropriate environmental goals and then to achieve them
- To integrate related environmental activities ever more fully throughout the Laboratory, with emphasis on seamlessly coordinating complex, multidisciplinary research
- To identify institutional and other barriers to implementing environmental technologies and beneficial industrial process modifications — from development to commercial deployment — and to identify methods of removing or mitigating those barriers
- To position Argonne as a critical national resource across the full spectrum of federal environmental responsibilities, including integrated environmental assessments and the development and implementation of improved environmental technologies and more environmentally benign industrial processes

Issues and Strategies

Multiple federal agencies will continue to have important responsibilities for environmental R&D programs. The needs of those programs and related funding decisions are expected to remain fragmented. The picture is further complicated by flux in the missions of DOE and other federal agencies as Congress changes priorities.

Test beds for new environmental technologies and large-scale user facilities devoted to environmental research can best be developed and operated by the national laboratories. Argonne plans to exploit its core competencies in these areas fully, in order to serve as an effective home for such national facilities.

Adequately addressing most of the important environmental issues facing the United States and the world requires the application of multiple scientific disciplines. Better solutions to environmental problems can be achieved by expanding the base of fundamental knowledge and by better applying what is already known. Both strategies deserve greater support.

Environmental research at Argonne demonstrates the unique ability of a national laboratory to marshall interdisciplinary R&D teams for long-term research. The Laboratory combines core capabilities in basic environmental systems — fundamental studies based in physics, chemistry, and biology — with capabilities to develop and apply new environmental research technology.

Notable future opportunities for Argonne's environmental programs lie in the areas of (1) environmental restoration and waste management; (2) natural resources; (3) environmental evaluations supporting the development and use of innovative energy systems; (4) assessment of environmental impacts from human activities; (5) environmental research; and (6) information systems that support better consolidation, visualization, and use of data.

The DOE Office of Environmental Management has existed since 1989, but its priorities and procedures are still evolving. To effectively serve DOE in the arena of

environmental restoration and waste management, Argonne's near-term strategy is threefold. First, the Laboratory will serve as a one-stop implementation center for applied R&D, featuring expedited site characterization, development and application of decision tools for site management, and development of innovative remediation technologies and processes. Second, the Laboratory will further develop supporting research programs in decision analysis, cost engineering, technology deployment, risk assessment and management, and information systems. Finally, Argonne will strive to maintain its status as lead laboratory in the area of deactivation, decontamination, and decommissioning, building on successes in solving its own problems of this type and on broad strengths in reactor engineering.

For the longer term, Argonne is working to build programs that more strongly integrate basic research with the development of environmental technologies, particularly through participation in DOE's Environmental Management Science Program.

The recent National Research Council report *Protecting the Environment* stresses the need for careful stewardship and management of both U.S. and global *natural resources.* Argonne is in an excellent position to help meet this need. In addition to work for DOE, Argonne helps the Department of Defense and the Department of the Interior in their responsibilities for federal lands, including use planning, maintenance, and stewardship. Argonne also provides technical assistance internationally, particularly in Asia to the United Nations Development Program and the Asian Development Bank. These efforts will require additional emphasis on emerging research areas, such as ecological risk, and on emerging developmental areas, such as geographic information and spatial analysis systems. The Laboratory will be strengthening and further integrating its ecology-related expertise, particularly to support the description and evaluation of long-term trends.

The nation will increasingly be competing for petroleum resources with emerging Asia-Pacific nations. As a consequence, environmental evaluations of new *energy systems* will increase in importance. Argonne's work in this area will be carefully coordinated with related Laboratory programs, notably work for the DOE Office of Energy Efficiency and Renewable Energy on general issues of energy efficiency, demand-side management, and integrated source planning and on certain issues relating to global change. Many of these studies will deserve extension to an international scope — especially to address the global issue of increased emissions of greenhouse gases, which are forecast to occur largely in Asia. Argonne's systems expertise will be particularly relevant to evaluating technological and process approaches to moderating growth in emissions of greenhouse gases. Current work in this area is supported in part by the World Bank and the Asian Development Bank.

The Laboratory's work in *environmental assessment* will continue to grow in complexity, requiring disciplinary strengths ranging even more broadly than in the past in order to provide state-of-the-art answers. Argonne will continuously address these evolving needs in order to remain a recognized world leader in environmental assessment.

The overall goal of the Laboratory's *environmental research* will continue to be development of the knowledge needed to address the nation's environmental problems. Combining the Laboratory's research with operation of major environmental user facilities, such as the Cloud and Radiation Testbed, will promote the development of stronger partnerships with environmental scientists in both universities and industry.

The scientific and technical information needed to make good environmental policy and design good environmental programs is vast, burgeoning, and extremely dispersed. Demands placed on *information systems* supporting decision making for federal environmental programs will continue to grow. The federal government needs better means of making more cost-effective decisions more rapidly, especially for complicated national issues where environmental objectives must be balanced with implications for industrial competitiveness, energy costs, and national security. Argonne can make important contributions to improving the

relevant federal information systems, especially in functions such as information retrieval, integration of large-scale databases, and the use of advanced spatial analysis and simulation technologies as analytical tools.

e. National Security

Situation

As the tensions of nuclear confrontation have diminished, Argonne's programs in national security have increasingly emphasized nonproliferation and counterproliferation, arms control verification policy and technology, low-enrichment fuel for research reactors, export control, international safeguards, and information management and planning. These activities are funded primarily by the DOE Office of Nonproliferation and National Security and the Department of Defense.

Vision

As the nation's foremost nuclear reactor laboratory, Argonne will apply its expertise in nuclear reactors and the nuclear fuel cycle, in conjunction with its unique nuclear facilities, to support federal programs that advance national security. The Laboratory will continue to strengthen its arms control programs in the areas of arms control verification, low-enrichment research reactor fuel, export control, and international safeguards and will build its current capabilities into a more highly integrated and broadly relevant program. The Laboratory will use its expertise in nuclear fuels and the fuel cycle to address problems created by excess plutonium from dismantled nuclear weapons and from nonmilitary activities as well. Argonne will also support counterproliferation initiatives through its expertise in mission planning, image exploitation, and information management.

Objectives

A leading goal is to develop new nonproliferation programs exploiting the Laboratory's expertise in nuclear fuel cycles and its facilities at Argonne-West. Specific objectives are as follows:

- To use the Laboratory's expertise and facilities to develop and evaluate new safeguards procedures and equipment
- To perform detailed analyses of nuclear fuel cycles for all reactor types, in order to improve understanding of their detectable signatures and their vulnerability to proliferation
- To develop new information and methods to better detect and evaluate the clandestine use of nuclear facilities for illegitimate purposes
- To evaluate further modifications to the designs of reactors and their operating modes that can reduce possibilities for nuclear proliferation

Issues and Strategies

The RERTR (Reduced Enrichment for Research and Test Reactors) program is the largest Argonne program in the national security area. It has already developed technology for converting most of the world's research reactors to use low-enriched (i.e., not weapons grade) nuclear fuel. With the world's best expertise on research and test reactors now at the Laboratory, the RERTR program should be extended to the remaining reactors that, for political or technical reasons, are not currently planning to convert to low-enriched fuel. (See Section V.A.6 for further discussion.) An agreement for an RERTR program in Russia has been completed, and one for China is being discussed.

Several current national security programs at Argonne were initially developed as part of the Advanced Concepts Program of DOE's Office of Arms Control and Nonproliferation. The Laboratory will continue to direct its work on advanced concepts toward the most promising of potential new technical initiatives.

The Laboratory's initiatives in the area of counterproliferation address problems associated with responding to the proliferation of weapons of mass destruction — nuclear, chemical, and biological. To meet this critical national challenge, Argonne will tailor and enhance capabilities developed for DOE, the

Department of Defense, and other federal agencies, including expertise in integrated mission planning, logistics, data fusion, information management, and image exploitation tools.

Argonne's expertise in reactors and its unique nuclear facilities are a national resource of great value for a number of specific national security needs. The Laboratory is preparing proposals that clearly articulate these opportunities. In preparation or under consideration are proposals to address anomalous reactor operations, tracking of nuclear fuel, assaying of spent fuel, disposal options for weapons plutonium, interim plutonium storage, enhancement of fuel cycle safeguards, and a comprehensive program to develop research reactor fuels by using low-enriched uranium. In general, Argonne concludes that U.S. nonproliferation efforts could benefit from greater emphasis on work related to nuclear fuel cycles and that the perspectives of a nonweapons laboratory with major experience in nuclear technology can be distinctly valuable for these efforts.

4. Educational Programs

Situation

Argonne offers to students, teachers, and other members of the nation's academic and technical communities unique opportunities for (1) participation in the Laboratory's research and (2) training in science and technology. These programs are based on diverse scientific and technical expertise and state-of-the-art equipment at the Laboratory. Augmenting the facilities of Argonne's research divisions for these purposes is exciting equipment dedicated specifically to educational programs, including a 2-MeV Van de Graaff accelerator and a van outfitted for science training at primary and secondary schools in the area. Small laboratories, an auditorium, and lecture rooms are available at the Laboratory for workshops, conferences, courses, and a variety of other instructional activities serving a full spectrum of participants. Foreign professionals participate in Argonne programs, both on-site and abroad.

Vision

Argonne will continue to enrich science education in the United States through a diversity of engaging, innovative opportunities for research participation and scientific training. In addition, the Laboratory will continue to follow national policy in providing training in energy-related technologies and other technical assistance to foreign countries.

Objectives

In pursuit of this vision, central Argonne objectives are as follows:

- To enhance the skills of U.S. educators and students in science, mathematics, engineering, and other technical fields
- To contribute to the reform of science education in the United States, particularly by developing innovative new programs and educational technology
- To foster continuous advancement of students — regardless of ethnicity or economic status — toward careers in science, mathematics, engineering, and other technical fields, and particularly to increase participation by under-represented minorities and disadvantaged students
- To facilitate development of a technically trained and diverse U.S. work force and generally to encourage scientific and technical literacy, particularly regarding energy, the environment, and the benefits of science
- To promote U.S. interests through international training and educational activities in science and technology

Issues and Strategies

Primary issues are (1) reduced overall funding for science education from the Office of Energy Research, (2) elimination of funding for precollege programs by Congress, and

(3) growing needs to enhance the science education pipeline and encourage diversity in the face of these diminishing resources.

Argonne is employing a variety of strategies to meet these challenges. Funding from other government agencies is being sought in coordination with DOE funding, and partnerships with external agencies are being developed and strengthened. In addition, the Laboratory's research divisions have responded by providing greater leveraging of educational funding for participants in their programs.

Argonne's educational programs are coordinated with those of scientific and educational organizations such as Sigma Xi, the DOE Science Education Directors Council, and the Education/Energy Compact. Linkages with museums, such as Chicago's Museum of Science and Industry, and similar learning centers have proven to be extremely valuable in reaching large numbers of precollege teachers and students. These partnerships will continue.

Even with reduced resources, Argonne has developed new initiatives to attract more underrepresented-minority participants to the Laboratory. Also planned are Argonne programs for students intending to become teachers of science and mathematics, with a focus as well on the faculty who teach these future teachers.

Argonne benefits from close relationships with a number of colleges and universities, both individually and through consortia such as Central States Universities, Incorporated, and Associated Colleges of the Chicago Area. Some of the Laboratory's ties to colleges and universities are cemented with memoranda of understanding and other types of formal agreements.

Serving DOE Mission Priorities

As first described in Chapter III, Argonne contributes importantly to each of the four primary mission areas of the Department of Energy:

- Energy resources
- Science and technology
- Environmental quality
- National security

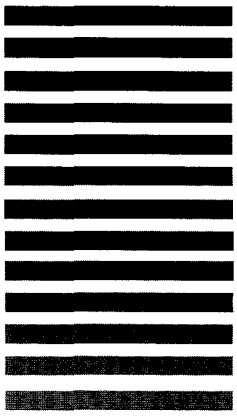
The three chapters that follow explain the nature of the contributions to the above mission areas that the Laboratory plans, both through its established programs and, for the longer term, through implementation of its R&D initiatives. The chapters address in turn

- Major R&D Initiatives (Chapter IV),
- Scientific and Technical Programs (Chapter V), and
- Technology Transfer and Science and Math Education (Chapter VI).

The major R&D initiatives presented in Chapter IV are the heart of Argonne's *Institutional Plan*. Development of these initiatives is the focus of the Laboratory's strategic planning process. Their implementation is crucial for Argonne's future contributions to DOE mission priorities and to other national goals as well.

Chapter V is the longest in the *Institutional Plan*. It provides a reasonably comprehensive description of the wide range of R&D programs at the Laboratory, organized by major DOE funding office or other sponsor. These descriptions complement the high-level overviews of the Laboratory's major programmatic thrusts already provided in Chapter III ("Strategic Plan").

Chapter VI considers in greater depth two Laboratory activities that depend crucially on close cooperation with nonfederal organizations: technology transfer to industry and enrichment of U.S. education in science and mathematics (one of the major goals that DOE includes in its core mission area of science and technology).



IV. Major Initiatives

Initiatives to open new areas of research are vital to the technical health and innovative spirit of any research organization. Argonne'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 the accomplishments and core competencies of the Laboratory.

New programs designated as Laboratory initiatives in this chapter are highlighted because they significantly affect all planning at Argonne, they will enhance national research capabilities, and they typically will affect patterns of research across several programmatic areas.

Other initiatives, designated as programmatic initiatives, are more closely related to research within a single program area; they are listed in Part B of this chapter and described in Chapter V. Programmatic initiatives are extremely important to the vitality of Argonne's research. Although individually they typically require a smaller commitment of resources than do Laboratory initiatives, each pushes at the frontier of technical knowledge in an important area.

Argonne received funding for several initiatives in FY 1996. They are still treated as initiatives in this document because they are in early stages of development, and their size and programmatic importance justify continued management attention. All funds received during FY 1996 are included in the programmatic resource projections in Chapter XII. However, resources required for initiatives in years beyond FY 1996 are generally not included in those projections. Projected resource requirements for the initiatives include costs associated with protection of the environment and the health and safety of workers and the public.

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.

A. Laboratory Initiatives

1. Center for Collaborative Science and Technology

Argonne proposes a major initiative to create a Center for Collaborative Science and Technology (CCST), which will focus on two major elements: (1) establishment of a major new computing facility supporting computational science and integrated collaborative research and (2) R&D to build, integrate, and use the core technology required for distributed collaborative science and technology.

The proposed CCST will provide a major DOE resource for high-performance computing and infrastructure to support remote electronic collaboration and use of large-scale experimental facilities. Technologies to be developed will enable a new generation of computational science applications that couple massive computations with immersive visualization. At the same time, these technologies will increase the productivity of researchers, particularly by enabling diverse teams to collaborate via high-speed networks without time-consuming travel.

Argonne is the ideal home for such a center. Following its successful creation in 1993 of the High-Performance Computing Research Facility to support computational science and engineering, the Laboratory has established itself as a recognized leader in virtual-reality technology. In mid 1994 Argonne organized the Computing and Communications Infrastructure Futures Laboratory, installed one of the nation's first Cave Automated Virtual Environments (CAVEs), and demonstrated the CAVE's use in significant scientific and industrial applications

at the SIGGRAPH 94 and Supercomputing '95 conferences. By immersing researchers in visualizations of their data, virtual-reality technology is providing new insights and faster understanding of complex, multidimensional phenomena.

The large-scale computing facilities supporting the CCST and its users will comprise four major components:

- *Compute server*, a several-hundred-gigaflop parallel computing engine providing the core computing power for underlying computational science problems
- *Storage server*, a high-capacity, high-bandwidth storage subsystem
- *Graphics rendering and geometry* server, the source of specialized power for driving a variety of immersive graphics displays
- *Digital media server*, the source of specialized power for handling multiple, simultaneous, interactive-media data streams (such as video and audio)

This new center will build both on specific knowledge gained at Argonne during the past three years and on the latest technology emerging from vendors.

Argonne is also playing a lead role in the exploration of advanced communications technologies, another area essential for implementing an electronic, distributed, collaborative research environment. The Laboratory is providing national leadership for the use of local and wide-area high-speed/high-bandwidth networking. Noteworthy examples are (1) the I-WAY (Information Wide Area Year) project, which focuses on mechanisms to link supercomputers and advanced visualization environments via asynchronous transfer mode, and (2) the LabSpace project, which is exploring electronic virtual laboratories to support remote operation and control of scientific experiments.

The CCST research programs addressing collaborative technologies will include topics such as

- Shared immersive virtual reality linked to supercomputers;
- Desktop-based collaborative environments;
- Multimedia, wide-area, and mass storage server environments;
- High-performance, secure, distributed computing tools; and
- Advanced networking R&D.

As successor to the High-Performance Computing Research Facility, the CCST will build on Argonne's successful program of research on high-performance computing and communications. The CCST projects will often involve cooperation among industrial partners; vendors; R&D programs at DOE laboratories; and large-scale, unique experimental user facilities, such as the Advanced Photon Source (APS).

Computational science and engineering programs using the CCST facility are expected to include

- Materials sciences;
- Physics, chemistry, and biology;
- Fluid dynamics and mechanics;
- Engineering mechanics and dynamics; and
- Large-scale optimization.

An important component of the proposed center is strong collaboration with leading computing centers (such as the National Center for Supercomputer Applications), national laboratories, and universities. Collaborators will complement Argonne's expertise in networking, visualization, and other advanced systems and will work jointly on computational science and computer science projects.

The CCST will require steady-state annual funding of $12 million. (See Table IV.1.) This support will have high impact because of very strong interactions with other Argonne capabilities and activities, particularly the CAVE and the IBM Scalable POWERparallel system, as well as associated new research, such as the LabSpace project. Support will be sought from

DOE, the Advanced Research Projects Agency, and vendors such as IBM. No major activities or costs related to the National Environmental Policy Act (NEPA) are anticipated.

Table IV.1 Center for Collaborative Science and Technology ($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	0.5	4.0	4.0	4.0	4.0	4.0	4.0
Capital Equipment	-	8.0	8.0	8.0	8.0	8.0	8.0
Construction	-	-	-	-	-	-	-
Total	0.5	12.0	12.0	12.0	12.0	12.0	12.0
Direct Personnel	3.0	20.0	20.0	20.0	20.0	20.0	20.0

2. Exotic Beam Facility

Opening of new frontiers for research in nuclear physics is expected through the acceleration of beams of unstable nuclei. 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 decays, reactions, and structure. All of these opportunities have triggered considerable excitement in the scientific community.

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. They 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 *1995 Long-Range Plan for Nuclear Physics*, prepared by the DOE-National Science Foundation Nuclear Science Advisory Committee (NSAC), gives highest priority to a radioactive beam facility as the major new construction project for the field.

Argonne has developed a facility concept that aims to achieve the physics goals set forth in the *ISL White Paper* and the NSAC *Long-Range Plan*. This Exotic Beam Facility will provide beams of the highest intensity required for research on nuclear structure and on reactions of astrophysical interest. The concept represents a cost-effective way to realize the benchmark facility described in the *ISL White Paper*.

Argonne's basic design concept for the Exotic Beam Facility is based on two accelerators. It uses a flexible approach for the primary production accelerator and 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 addition, experimental equipment at ATLAS, including recently completed novel instrumentation like the fragment mass analyzer, is well suited to nuclear structure research.

Argonne's Exotic Beam Facility 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 perhaps two years of detailed facility design. Required resources are specified in Table IV.2. Funding is being sought from the Nuclear Physics (KB-02) program. No major NEPA-related activities or costs are anticipated.

Table IV.2 Exotic Beam Facility
($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	0.1	0.5	1.0	1.7	2.7	6.4	14.5
Capital Equipment	0	0	0	0	3.3	5.6	3.0
Construction	0	0	0	56.0	79.2	24.2	0
Total	0.1	0.5	1.0	57.7	85.2	36.2	17.5
Direct Personnel	0.5	2.0	4.0	7.0	10.0	20.0	45.0

3. APS Beamlines

The APS facility now nearing completion at Argonne will be operational by the end of 1996. It will ultimately provide 70 X-ray sources of unprecedented brightness to meet the research needs of virtually all scientific disciplines and many critical technologies. Current funding will support completion of an initial complement of beamlines. Starting in FY 1999, additional beamlines will be needed to advance the state of the art in X-ray science. The present initiative has two main goals: (1) to provide standard beamline components to technological and academic users forming collaborative access teams and (2) to support the unexpectedly large demand for bright X-ray beams that cannot be met within the scope of the APS project already funded.

Comprehensive exploitation of the unique properties of APS beams will enable cutting-edge research not currently possible. The new facilities provided under the APS Beamlines initiative will target the most critical scientific and technical goals of the U.S. X-ray community. The APS facilities will be universally available to researchers from universities, federal laboratories, and industry, on either a peer-reviewed or proprietary basis. The present initiative will also provide in a timely manner the additional beamlines and insertion devices required to meet user needs as new collaborative access teams are formed.

The importance of the APS facility for U.S. scientific and technological advancement is clear. European countries have jointly built a facility in Grenoble, France, that is similar to the 6-7 GeV synchrotron radiation source being built at Argonne. The Japanese are building a facility in Nishi-Harima that will be larger than the APS facility, even after completion of this initiative.

The APS Beamlines initiative will support construction of 2.5-meter-long insertion devices, to be employed as X-ray sources on four straight sections of the APS storage ring. In addition, four bending-magnet radiation sources will be put into use. The front-end optics and controls for these X-ray sources will be built to contain the bright X-ray beams of the APS and to safeguard access to them. Additional funds are required to build standard beamline components that meet the scientific and technological research demands of the collaborative access teams at the APS.

In compliance with NEPA provisions, Argonne prepared an environmental assessment for the APS project. The assessment included the scope of the present APS Beamlines initiative. The assessment resulted in a finding of no significant impact, which was issued by DOE in May 1990. Activities planned under the present initiative remain consistent with the originally assessed project scope.

The "APS Beamlines Initiative" (Project 94-CH-057) is proposed to begin in FY 1999 and to be completed in FY 2002. A conceptual design report describes the scope of the proposed technical and conventional construction and details costs and schedules. Total estimated cost is $57.7 million. Funding is sought from the Materials Sciences (KC-02) program. Required resources are described in Table IV.3.

Table IV.3 APS Beamlines
($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	-	-	-	2.2	3.3	7.7	11.0
Capital Equipment	-	-	-	-	-	-	-
Construction	-	-	-	3.4	23.2	17.3	13.8
Total	-	-	-	5.6	26.5	25.0	24.8
Direct Personnel	-	-	-	4.0	14.0	14.0	14.0

4. Mechanistic Biology

Argonne proposes a major initiative in Mechanistic Biology comprising three integrated programs. The first is the Structural Biology Center, a major user center at the APS that has been approved for development by APS management and funded by the DOE Office of Health and Environmental Research. The other two programs, the Human Genome and Computational Biology, will examine the structure and function of DNA and other biological macromolecules. Table IV.4 summarizes total resource requirements for the three component programs.

Table IV.4 Mechanistic Biology
($ in millions BA; personnel in FTE)[a]

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	2.2	4.6	5.2	5.2	5.2	5.2	5.2
Capital Equipment	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Construction	4.3	-	-	-	-	-	-
Total	7.1	5.2	5.8	5.8	5.8	5.8	5.8
Direct Personnel	11.2	27.3	28.6	28.6	28.6	28.6	28.6

[a]Estimates for FY96 include resource projections for a new genome project currently supported under KP-04-04.

The Structural Biology Center will enhance U.S. capabilities in structural biology by constructing a user facility at Argonne's APS. Research into the structure, function, and kinetics of (1) nucleic acids and proteins and (2) large aggregates such as viruses and ribosomes promises to revolutionize our understanding of molecular biology and hence our understanding of disease processes, immunity, photosynthesis, catalysis, industrially useful biochemical processes, and basic biological science. The experiments to be performed require the brilliance of the APS beamlines.

Argonne's Structural Biology Center will be organized and operated as a collaborative access team to develop, equip, and operate one sector of the APS, which will be openly available to all qualified scientists for the study of structural biology. The Center will furnish all necessary X-ray optical equipment, experimental facilities, and computer equipment and software, along with staff qualified to work with outside users. These services will reduce barriers to use of the APS by the structural biology community.

In parallel with development of the Structural Biology Center facility, development of instruments for biophysical applications of synchrotron radiation is an immediate need. Almost all biophysics experiments now using synchrotron radiation are seriously limited by inadequate X-ray detectors. Argonne is now developing a new two-dimensional area X-ray detector, based on the charge-coupled device (CCD) sensor, that will handle the immense X-ray photon flux of the APS and will be immediately useful at existing synchrotron sources. Since the CCD detector integrates the signal but does not count photons, its measurement rate has no limit. Funding for development of detectors is not included in Table IV.4.

Funding for construction of the Structural Biology Center was initiated in FY 1994 under the Biological and Environmental Research (KP) program. Completion of construction is scheduled for the second quarter of FY 1997.

In the second component of the Mechanistic Biology initiative, Argonne scientists have embarked on a major program of DNA sequencing as a component of the DOE Human Genome project. The Laboratory is employing the approach of sequencing by hybridization on oligonucleotide microchips (SHOM). This approach, which is being developed jointly by scientists from Argonne and the Engelhardt Institute of Molecular Biology, Russian Academy of Science, can increase the efficiency of genome DNA sequencing by orders of magnitude. The SHOM technique is based on highly specific interactions between complementary DNA sequences. The DNA is read in terms of "words" or "sentences" by using a sequencing microchip, rather than by conventional "letter-by-letter" (base-by-base) sequencing.

The technology required to implement SHOM is under development. Substantial progress has already been made. A robot has been built that applies a minute amount of oligomer to defined elements of the microchip.

The conditions for reliable hybridization of DNA to the oligomers on the microchip have been determined, and a special fluorescent microscope for reading the microchip has been devised. The potential efficiency of the SHOM technique has been demonstrated through reliable identification of specific DNA sequences. Efforts have begun to sequence short DNA lengths corresponding to specific genes, as an intermediate step in genome sequencing.

The technology developed will be used to manufacture microchips incorporating long, immobilized pieces of DNA. Such microchips will find a variety of applications in biology, biotechnology, and medicine. Examples include diagnostic tests for genetic diseases, gene polymorphism studies, identification of many different microorganisms in a single sample, and comparative studies of the genomes of many different individuals and organisms. Like electronic microchips that treat a huge amount of general information, these biological microchips can be built to collect and analyze a large amount of biological information in a few experiments.

Opportunities to develop a SHOM research collaboration with one or more industrial partners are being explored, because the SHOM technique, when fully developed, is expected to be effectively transferable to the private sector. Other Argonne DNA sequencing research involves a technique called "primer walking," which eliminates the need for the primer synthesis step required in conventional sequencing. Development of primer walking will fully automate the complete cycle of sequencing. In combination, SHOM and primer walking techniques will advance the state of the art in genome sequencing and will open new applications that can exploit the microchip concept. Funding is being provided by the Office of Health and Environmental Research.

These Human Genome projects have been established in existing, conventional, small-scale research laboratories at Argonne. The activities are conducted in accordance with established Laboratory programs and procedures for environmental protection.

The third component of the Mechanistic Biology initiative is Argonne's program in Computational Biology, which investigates relationships between structure and function in biological macromolecules. It complements and interfaces with the Structural Biology Center and the Human Genome project, as well as with the Laboratory's Center for Collaborative Science and Technology initiative. This initiative (Section IV.A.1) will provide high-performance computing capabilities to support the essential computational and modeling needs of the other programs.

Synergism among all these facilities and programs will significantly improve methods and capabilities for computational biology. A primary goal will be to develop computational techniques for querying nucleic or amino acid sequence databases in order to develop reliable correlations between the sequences and corresponding three-dimensional structures and functional characteristics. Information on protein structures from theoretical prediction and experimentation will be better analyzed by using massively parallel computing and novel mathematical methods. In addition, Argonne is developing new methods for representing the shapes and chemical properties of molecules and for studying reaction mechanisms for enzyme systems, in order to analyze efficiently and accurately the recognition and catalytic properties of biological macromolecules. These methodologic advances will provide the basis for progress in several important areas of molecular biology, including (1) protein folding and design, (2) molecular recognition and drug design, and (3) enzyme catalysis and design.

Combining advanced computing resources and state-of-the-art biophysical facilities will place Argonne at the forefront of computational research in the biological sciences. The Computational Biology program promises significantly better understanding of basic biomedical problems, along with an effective mechanism for transferring advanced computational methods to the biotechnology industry.

Argonne's work in computational biology is primarily data analysis supported by laboratory

research conducted in accordance with established programs and procedures for environmental protection. Initial funding is being provided by the Biological and Environmental Research (KP) program.

5. Advanced Pulsed Neutron Source Technology Development

Neutron scattering has provided critical microscopic information on the structure and dynamics of condensed matter for more than four decades. This contribution has been crucial to our basic understanding of materials in fields as diverse as materials science, physics, chemistry, earth science, and biology. In addition, neutron scattering has significantly increased understanding of materials in technologically important areas such as chemicals, electronics, aerospace, energy production and conversion, advanced batteries, and biological materials. The 1994 Nobel prize in physics acknowledged the accomplishments of two early workers in neutron scattering, Clifford Shull and Bertran Brockhouse.

The need for more intense neutron sources has been confirmed by many meetings and reports. The most recent workshop, held at Argonne in May 1993, concluded that the case for a new, higher-flux pulsed neutron source is extremely strong. Such a facility will lead to qualitatively new advances in the science of condensed matter. Participants also concluded that unique scientific opportunities exist at both the next-generation reactor neutron source and the next-generation spallation source, as well as a broad middle ground where both facilities can make significant contributions. The two top recommendations in a study pursued by the Basic Energy Sciences Advisory Committee (BESAC) Panel on Neutron Sources were to

- Complete the design and construction of the Advanced Neutron Source (ANS) and
- Immediately authorize the development of competitive proposals for the cost-effective design and construction of a 1-MW pulsed spallation source.

Subsequently, DOE's budget submission for FY 1996 terminated the ANS because of its high cost.

For several years, Argonne has been examining the feasibility of an Intense Pulsed Neutron Source (IPNS) Upgrade (see *IPNS Upgrade: A Feasibility Study*, April 1995). Based on a proton accelerator producing 500 μA at 2 GeV, the Upgrade could provide a total beam power of 1 MW. One of two target stations would operate at 10 Hz for high-resolution and long-wavelength instruments; the other would operate at 30 Hz for high-intensity applications. The Upgrade could be accomplished relatively quickly with modest extensions of existing technology at a total estimated cost of $559 million. Use of existing Argonne buildings would save $175 million relative to the cost for a greenfield site. As a further development, a 10-GeV ring could be built to boost beam power to 5 MW.

The potential for significant near-term increases in neutron-scattering capabilities at accelerator-based spallation neutron sources is great. A 1-MW facility would exceed by a factor of six the present power of ISIS in the United Kingdom, currently the world's most powerful spallation neutron source.

To update its review of future U.S. neutron sources after cancellation of the ANS, BESAC established three committees that met in January 1996. Their respective charges are (1) to review possible upgrades of existing reactors, (2) to review possible upgrades of existing spallation sources, and (3) to guide DOE's conceptual design of a new spallation source. The congressional conference report on the FY 1996 Energy and Water bill made "no recommendation on the siting of the new spallation source project. The DOE shall make the determination in a fair and unbiased manner." As the most complete study for a new spallation source in existence, Argonne's *IPNS Upgrade: A Feasibility Study* has been a valuable baseline for the third BESAC committee and for future source designs.

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. The Laboratory will be assisting design studies in these areas at both Los Alamos National Laboratory and Oak Ridge National Laboratory.

6. Advanced Nuclear Technology

No new orders for nuclear power plants have been placed in the United States in over two decades. As work on the final plants under construction winds down, U.S. nuclear vendors have reduced staff greatly. The Integral Fast Reactor (IFR) program was terminated in FY 1995, the Advanced Light-Water Reactor program will be terminated after FY 1996, and enrollments in nuclear engineering programs at universities across the country have dropped precipitously. The U.S. nuclear technology infrastructure, which once led the world, has been eroded seriously and could be lost almost entirely if present trends continue.

Yet the United States still has 108 operating nuclear power plants producing about 20% of the country's electric power, and worldwide a large and growing market for nuclear technology is projected, especially in China and other Asian countries. The United States needs a strong nuclear technology infrastructure to support the safe and efficient operation of domestic nuclear power plants, to compete in the growing world market, and to influence international affairs relating to nuclear power.

During its 50-year history, Argonne has played a key role in the development of nuclear reactor technology from the early pioneering days through the terminated IFR program. Several U.S. laboratories possessed broad nuclear reactor expertise in the past, but Argonne is currently unique in that respect. It is the only remaining laboratory with 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.

To alleviate the decline in U.S. nuclear technology infrastructure, Argonne proposes a program with the following central goals:

- Maintain a complete core competency in nuclear technology so that the nuclear option is not lost to the United States for the long term
- Support U.S. international competitiveness in nuclear technology while fostering international cooperation as appropriate
- Focus in the near term on priority issues of improving the safety and efficiency of existing reactor operations, as a bridge to longer-term objectives

To achieve these goals, Argonne proposes an initial research program focusing on key light-water reactor technologies. The following four areas will be addressed:

- *Advanced Computing Applications:* Reduce operating costs or improve the reliability and safety of current reactors through techniques including advanced diagnostics, sensor validation, and high-fidelity real-time simulation.
- *Reactor Materials Research:* Extend the lives of aging reactors and their components.
- *Nuclear Safety R&D:* Refine and limit risks from nuclear plants. (See Argonne's related initiative on international cooperation in nuclear safety and nonproliferation, Section IV.11.)
- *Fuel Minimization:* Extend fuel burnup to reduce both the waste requiring disposal and fuel costs.

Funding for the Advanced Nuclear Technology initiative will be sought from the Office of Nuclear Energy, Science and Technology (AF).

7. Advanced Transportation Technology

Argonne proposes to expand its current research, development, and analysis of advanced transportation technologies for DOE and other federal agencies by establishing a

Center for Advanced Transportation Technology. The objective of this initiative is to work cooperatively with U.S. industry to develop and implement cost-effective technologies to improve the fuel efficiency of and reduce the environmental emissions from advanced transportation systems. The initiative comprises three major activities: (1) automobile research, conducted as part of the national Partnership for a New Generation of Vehicles (PNGV); (2) research on heavy-vehicle technology, involving the national laboratories and truck manufacturers; and (3) intelligent transportation systems (ITS). These three areas encompass research on advanced diesel engines, batteries, hybrid vehicles, supercomputing, vehicle recycling, railroad systems, and ITS sensor and data processing technology. Each of these research areas is described briefly below.

Advanced Diesels. Diesel engines offer the potential for significant improvements in the fuel economy of automobiles and can be enhanced to provide further energy efficiencies in trucks and locomotives. Controlling emissions of nitrogen oxides (NO_x) and particulate matter remains a key technical hurdle, especially as emissions regulations become tighter. Argonne has a CRADA with the Association of American Railroads (AAR) to investigate the potential for reducing locomotive emissions through oxygen enrichment. A work-for-others agreement with the ElectroMotive Division of General Motors involves researching, designing, and developing subsystems, components, fuel systems, and emission controls for EMD's new generation of locomotive diesel engines. In another project, Caterpillar is supporting an exploration of the potential of a NO_x control device developed by the Laboratory. Argonne also has a prominent role in research on the compression-ignition, direct-injected engine, to help PNGV meet its goals.

Batteries. Electric and hybrid vehicles represent cleaner, more efficient alternatives to the internal combustion engine. The market for these vehicles is increasing because of more stringent environmental regulations enacted in California and several other states. In January 1991, Ford, General Motors, and Chrysler formed a partnership to develop advanced batteries for electric vehicles. The Electric Power Research Institute later joined the domestic auto manufacturers to form the U.S. Advanced Battery Consortium. With support from government and industry, Argonne is conducting R&D on lithium-polymer, lithium-ion, and nickel-metal hydride batteries, as well as on galvanic ultracapacitors. All of these technologies are being developed internationally as advanced energy storage technologies for application to light-duty electric and hybrid vehicles.

Hybrid Vehicles. Hybrid vehicles can be improved to overcome important limitations of electric vehicles — especially range and recharging rate — and thereby to achieve greater acceptability in the market. A hybrid vehicle employing either a small internal combustion engine or a gas turbine with a battery could perform as well as a conventional vehicle but be far more energy efficient and environmentally benign. In the long term, a hybrid vehicle powered by fuel cells could offer nearly twice the energy efficiency of a conventional vehicle and would further reduce emissions. In support of DOE's program to develop hybrid propulsion systems, Argonne is the lead DOE laboratory for R&D on transportation fuel cells and designs for high-power batteries.

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 four other DOE laboratories are collaborating with the University of Michigan and the Big Three automakers. The Partnership will create software for high-performance computer systems that will cut the time required to design and test new concepts for advanced power plants, aerodynamic shapes, and improved safety features. Reduced time to market should make the U.S. manufacturers more competitive internationally. The focus will be on leading-edge computing systems, such as massively parallel supercomputers; advanced computational engineering software for fluid dynamics, structural mechanics, and computer-grid-generation technology; and rapidly evolving visualization, such as virtual reality.

Recycling. Obsolete motor vehicles contain plastics, chlorofluorocarbons, rubber, glass, and certain heavy metals that are not currently recyclable and must be deposited in landfills. The cost of environmentally acceptable disposal of these materials and the associated contaminants from auto shredder residue has risen, threatening the economic viability of recycling. Ford, General Motors, and Chrysler recently formed the Vehicle Recycling Partnership to examine such issues. Under a CRADA with the Vehicle Recycling Partnership and the American Plastics Council, Argonne will be developing technologies for processing waste streams that result from recycling obsolete cars, as well as comparing the cost-effectiveness, energy efficiency, and environmental acceptablility of alternative systems for handling the waste streams.

Railroad and Electromagnetic Technologies. New technologies are needed to maintain and improve the existing U.S. railroad system and to meet future demands for increased fuel efficiency, reduced emissions, higher speeds, and greater axle loads. In response to a request by DOE Energy Research that its laboratories develop partnerships with key U.S. industries, Argonne has joined AAR to help the freight railroad industry address these needs. In a pilot program with AAR, Argonne is currently studying oxygen-enriched combustion. The Laboratory is also serving as DOE's technical lead in a cooperative government-industry maglev research program. In other work, the Laboratory is continuing to develop and validate computational codes and build small-scale experimental facilities to help the government evaluate and test alternative electromagnetic propulsion systems.

Intelligent Transportation Systems. More effective use of technology is urgently needed to make driving on U.S. streets and highways safer and more efficient. In response to this need, Argonne has joined a national effort to improve automotive transportation through intelligent transportation systems relying on advanced electronic and communications technologies, advanced computing, sensors and instrumentation, and information management systems. The Laboratory's work will exploit its experience in developing computer simulations of complex systems, using high-performance computing and display systems, developing sensors and instrumentation, and conducting integrated environmental assessments. Argonne is currently participating in the Chicago-based ADVANCE ITS project, the nation's largest demonstration of an intelligent transportation system, and is providing technical support for Minnesota's GUIDESTAR project.

Funding for this research is sought from DOE-Laboratory Technology Research (KU), from two programs within DOE-Energy Efficiency (Transportation [EE] and Industrial [ED]), and from the Department of Transportation. See Table IV.5.

Table IV.5 Advanced Transportation Technology
($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	14.4	17.8	21.4	25.4	28.4	29.0	29.0
Capital Equipment	0.9	1.4	1.9	2.3	2.3	2.3	2.3
Construction	-	-	-	-	-	-	-
Total	15.3	19.2	23.3	27.7	30.7	31.3	31.3
Direct Personnel	72.0	83.0	92.0	102.0	110.0	110.0	110.0

8. Industrial Energy Efficiency

The industrial sector accounts for approximately a third of the energy used in the United States, at a cost of about $100 billion each year. This energy is used to generate heat and steam for industrial processes; to power stationary motors and machines; to light, heat, and cool factories and offices; and to power vehicles. Oil and natural gas also serve as feedstocks for manufacturing plastics and other materials.

Five 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 the waste and 95% of the air pollution from manufacturing, and account for about a third of U.S. carbon dioxide emissions. High energy use and waste production are not surprising in process industries, whose function is to convert raw materials into intermediate products for

fabrication and assembly in the automotive, electronics, aerospace, and construction industries, among others. Reflecting the importance of the industrial sector, DOE's Office of Industrial Technologies has structured an Industries of the Future program that is working with major U.S. industries to develop a shared vision of the future and a roadmap of research needs.

In response to this vision and research roadmap, Argonne proposes a concerted initiative targeting the energy-intensive industries that will conduct research to improve energy efficiency, increase resource recovery and reuse, and generally improve the productivity of the U.S. process industries and make them more competitive relative to producers abroad. Four industries will receive central attention: chemicals, petroleum refining, forest products, and steel and aluminum. The initiative will build on facilities, research programs, and staff that the Laboratory has developed in work for DOE and other federal agencies. It will also take advantage of Argonne's location in the U.S. industrial heartland and the good relations and partnerships with many industrial firms and associations that the Laboratory has established over the past decade.

a. Chemicals Industry

Over the past two years, the chemicals industry has developed a vision, *Vision 2020*, through the combined efforts of the Chemical Manufacturers Association, the American Chemical Society, the American Institute of Chemical Engineers, the Council for Chemical Research (CCR), and the Synthetic Organic Chemicals Manufacturing Association. Argonne supports roadmap development through participation in the CCR process. Particularly relevant are the Laboratory's ongoing R&D programs addressing recovery and reuse of polymers, development of chemicals from alternative feedstocks, bioconversion of high-starch wastes to high-value products, and plasma chemical processing. Argonne has achieved a preeminent position in the development of processes to recover and separate high-value plastics from obsolete appliances, auto shredder residue, and post-consumer wastes. The Laboratory has designed and is ready to pilot test a continuous-cleaning and -drying apparatus for recovered foam. Under construction and scheduled for testing in FY 1997 is a continuous pilot process for separating acrylonitrile-butadiene-styrene (ABS) plastics from high-impact polystyrene (HIPS) with better than 99% efficiency.

In collaboration with Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), National Renewable Energy Laboratory (NREL), and Idaho National Engineering Laboratory, Argonne is developing improved processes to convert bio-based materials into chemicals and precursor chemicals that can displace petroleum-derived feedstocks. Argonne has developed a new genetic strain of bacteria that produces succinic acid (a desirable chemical intermediate) at higher concentrations and speed than were previously achieved. Argonne, ORNL, PNNL, and NREL have signed a CRADA with a private company to commercialize this technology. Argonne also has several CRADAs and other agreements with private companies to develop the production of "green solvents" from bio-based high-starch raw materials. Under the proposed initiative, Argonne will work with the CCR and other chemical industry organizations to bring chemistry and chemical engineering technologies developed with earlier DOE support to bear more fully on high-priority problems identified by the industry's vision and roadmap.

b. Petroleum Refining Industry

Argonne has played a key role in developing a vision for the petroleum refining industry, particularly by assisting DOE in early planning and evaluation for collaborative research with industry. The Laboratory coordinated the identification of national laboratory capabilities relevant to research given high priority by the refining industry and published the results on the World Wide Web. Moreover, Argonne has helped to organize and lead a "virtual laboratory" for petroleum refining; altogether, 12 national laboratories are cooperating to identify areas of expertise and

capabilities that will be valuable for the industry. These activities have matured to the point that the main industry organization, the American Petroleum Institute, is regularly presenting problems in need of research for consideration by the virtual laboratory.

Argonne is working with UOP and Chevron to develop an advanced fluid catalytic cracker designed for the feedstocks that refineries will face in the near future. Rapid commercialization is expected.

To address the critical problem of fouling in refinery operations, Argonne is working with several refiners to test the fouling characteristics of real-world refinery streams; Argonne designed and assembled and is now operating fouling monitors in multiple industrial settings. Argonne is also working on the upgrading of heavy oils, through programs investigating the catalytic conversion of California crudes, the upgrading of residuum, and the use of fluidized beds. Under the proposed initiative, the Laboratory plans to apply its expertise in catalytic, process engineering, and computational fluid dynamics modeling, in collaboration with industry, to address this key problem.

c. Forest Products Industry

The American Forest and Paper Association (AF&PA) has also prepared a vision for its industry in the year 2020. *Agenda 2020* identifies six priority research areas that are critical to reaching the industry's productivity and environmental goals in the next century: sustainable forestry, environmental performance, energy performance, improved capital effectiveness, recycling, and sensors and controls. For each priority area, the AF&PA has organized task groups that are determining the most important research projects.

In collaboration with the Institute of Paper Science and Technology, Argonne is developing an electrodialysis process for removing non-process elements from bleach plant filtrates, so that water can be recycled after bleaching rather than being used once and discharged to a stream. With three other national laboratories, Argonne is also involved in a program to develop optical sensors for continuous measurement of the paper web during paper making. In partnership with the University of Maine and an industrial partner, the Laboratory is working to apply intelligent control systems in the pulp and paper industries, exploiting technology developed earlier for DOE's nuclear reactor program. The new control systems are expected to reduce significantly the cost of operating paper mills. Through the proposed initiative, Argonne expects to develop many more innovative energy and environmental technologies for application in the forest products industry.

d. Steel and Aluminum Industry

The American Iron and Steel Institute (AISI) is leading the development of a vision and roadmaps for its industry. Argonne is working with AISI to develop standardized contract language for cooperative programs involving government laboratories and the steel industry. The agreement is to be broadened in coming months for nonferrous metals industries such as aluminum. This standardization is expected to allow DOE's laboratories to respond more quickly to the needs of the metals industries.

In partnership with Metals Recovery Industries, Inc., Argonne has already developed a process for dezincing galvanized steel. Operations are underway at a pilot plant with annual capacity of 50,000 tons, and establishment of the first commercial demonstration plant is being negotiated.

Secondary aluminum smelters generate salt cake that contains metal, oxides, and salt. If it is not recycled, the salt cake must be deposited as waste in landfills at substantial cost. Argonne is working with aluminum industry associations to develop separation processes and markets for the materials recovered from salt cake, including aluminum and raw materials for production of insulation and firebrick.

Resources required for this concerted Industrial Energy Efficiency initiative are summarized in Table IV.6. Funding is being

sought from the DOE Office of Industrial Technologies and from the industries.

Table IV.6 Industrial Energy Efficiency
($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	6.5	9.3	10.1	11.7	12.4	13.4	13.7
Capital Equipment	<0.1	0.1	0.2	0.2	0.2	0.2	0.2
Construction	-	-	-	-	-	-	-
Total	6.6	9.4	10.3	11.9	12.6	13.6	13.9
Direct Personnel	33.4	40.0	46.0	50.0	52.0	53.0	53.0

9. Advanced Environmental Technologies

The DOE Office of Environmental Management is developing a ten-year plan that focuses on cleaning up most DOE sites within a decade. The new plan includes the application of new technologies researched over the past six years (through support by the DOE-Environmental Management Science and Technology program), which are currently at various points along the development-and-demonstration pipeline. Despite ongoing cleanup efforts and activities planned for the next ten years, few DOE waste streams associated with weapons production are expected to be treated substantively over that planning horizon. Not slated for complete remediation or permanent disposal by 2006 under the DOE-Environmental Management plan are high-level wastes, spent nuclear fuel, materials associated with plutonium disposition, and other special nuclear materials. 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) electrometallurgical technology for spent nuclear fuel, (2) technologies for treating mixed waste, (3) technologies for decontamination and decommissioning (D&D), (4) waste form development, (5) advanced innovative technologies, and (6) assessment and management of risk. Argonne's electrometallurgical process is the only technological option currently being developed for treatment of spent fuel. DOE-Nuclear Energy, Science and Technology is supporting application of this technology to EBR-II spent fuel, but the process has numerous applications to other DOE spent fuels as well.

Efforts on mixed-waste treatment and D&D are logical extensions of Argonne's broad background in reactor technology. The D&D activities build on successful ongoing projects at the Laboratory, including those at the Experimental Boiling Water Reactor and the CP-5 Reactor. In mixed-waste treatment, Argonne specializes in remote handling operations and transuranics. Facilities at Argonne-West are uniquely suited to such R&D.

Projects on waste form development and advanced innovative technologies involve the integration of applied engineering, basic materials science, and basic chemical science. Development of waste forms is very important for solving problems associated with high-level waste, mixed waste, and waste stabilization. Advanced innovative technologies primarily depend on the development of better separations and extractions, improved sensors, and better understanding of interactions among radioactive elements in various media and waste forms. In work over many years for DOE, the Department of Defense (DOD), the Department of Agriculture, and the National Science Foundation, Argonne has developed substantial capabilities for site assessment and risk management. Salient technologies and processes developed

include (1) Adaptive Sampling Strategies (developed in part through a CRADA with Consolve, Inc.), (2) QuickSite℠ (the basis for an ASTM [American Society for Testing and Materials] standard for expedited site characterization), (3) RESRAD (a model for assessing environmental pathways and risks associated with radionuclides), and (4) guidance for land use after remediation. These technical advances have yielded significant benefits in the areas of site characterization, risk assessment tools, ecological risk assessment guidance, and waste transportation and associated risk evaluation.

Argonne continues to play an important role in environmental technology programs for DOE-Environmental Management and the Army Environmental Center. Although DOD is not likely to fund environmental R&D after 1997, radionuclide-containing wastes produced by DOE will remain a major DOE issue beyond 2006, justifying the development of technologies that are more cost-effective and better grounded scientifically. For the longer term, development of technologies applicable to the nation's huge problems with mine waste may lead to funding from the Department of the Interior.

Resources required for this initiative are summarized in Table IV.7. Funding will be sought from DOE-Environmental Management (EW), DOE-Nuclear Energy Research and Development (AF), and DOD.

Table IV.7 Advanced Environmental Technologies ($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	40.0	45.0	50.0	60.0	60.0	60.0	60.0
Capital Equipment	-	1.0	2.0	2.0	-	-	-
Construction	-	-	-	-	-	-	-
Total	40.0	46.0	52.0	62.0	60.0	60.0	60.0
Direct Personnel	160.0	180.0	200.0	235.0	235.0	235.0	235.0

10. D&D Technology Center

The deactivation, decontamination, dismantlement, and decommissioning of nuclear reactors and related facilities (such as hot cells, glove boxes, and fuel storage vaults) represent a major challenge for DOE and the commercial nuclear industry, both in the United States and abroad. Aging DOE nuclear facilities, constructed as early as the 1940s, need to be decommissioned, with their sites restored for other uses. The commercial nuclear industry faces the same problem, though with some time lag. Problems associated with decontamination and decommissioning (D&D) include safe and effective dismantlement of contaminated and radioactive components; packaging, transportation, and disposal of waste; and recycling and reuse of the maximum possible amount of material. Internationally, the total expense of this work has been projected to exceed $500 billion over the next several decades. There is a clear need to develop, demonstrate, and use effective technologies for this endeavor, in order to ensure worker and public safety, minimal costs, and timely completion.

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, a number of reactors and related facilities at the Laboratory are ready for D&D. These facilities are prototypes of systems used commercially, and they therefore will provide excellent test beds for the demonstration of D&D technologies under controlled laboratory conditions. Such demonstrated technologies can then be transferred to industry for use domestically and internationally. This technology development and demonstration will be pursued simultaneously with the D&D on Argonne facilities, so that the work on Laboratory facilities can be completed on schedule while the broader missions of the Center are pursued.

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

- To develop, test, and validate the full range of methods used for cost-effective and safe D&D of nuclear facilities
- To use as test beds for demonstrating methods developed both at the Laboratory and elsewhere the broad array of Argonne facilities that are on the D&D schedule of DOE-Environmental Management
- To develop and validate methods for the future D&D of the Experimental Breeder Reactor-II at Argonne-West
- To coordinate a team of D&D specialists from both the national laboratories and the private sector to achieve cost-effective D&D for the DOE complex
- To transfer the most effective D&D technologies to the private sector for use in commercial D&D
- To participate in international D&D activities via various technology assessment groups and to support D&D being provided to the former Soviet Union
- To help U.S. industry compete effectively for international D&D jobs

Assembly of a broad consortium of outside organizations to support Argonne's D&D Technology Center has begun. The Laboratory's strategic plan for the center has been endorsed by the DOE Chicago Operations Office and incorporated into that office's own long-term planning. Several industrial organizations have joined the consortium, including large companies (3M, Raytheon, and ICF Kaiser), smaller companies (such as MACTEC and Nuclear Fuel Services), and major utilities (Duke Power and Commonwealth Edison). In addition, universities (Florida International University, the University of New Mexico, and the University of Illinois) and other national laboratories have agreed to participate.

Recognizing the magnitude of the nation's D&D problems, DOE-Environmental Management has designated D&D as one of its major focus areas. The Morgantown Energy Technology Center has been assigned the lead role for the program. Argonne, along with its industrial partners and the DOE Chicago Operations Office, is prepared to play a major role, building on the selection of the Laboratory's CP-5 Reactor as the site of the program's first D&D demonstration project.

The initial DOE support for D&D research and development at Argonne was redirected from funding for the Laboratory's Integral Fast Reactor program. Future funding is anticipated from DOE-Environmental Management (EM-50 and EM-40) and from electric utilities. Support for some international activities is expected from defense conversion funds. Resources required for Argonne's work are summarized in Table IV.8.

The D&D Technology Center is expected to encompass a wide variety of projects. NEPA evaluations will be performed for individual projects in accordance with a NEPA plan for the Center and Argonne requirements. None of the currently envisioned projects is expected to have significant environmental impact. Projects associated with ongoing D&D operations scheduled by DOE-Environmental Management will also be evaluated separately, even though they are likely to be covered by the NEPA documentation for these D&D operations.

Table IV.8 D&D Technology Center
($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	3.3	4.5	6.0	7.0	7.5	8.0	8.0
Capital Equipment	0.2	0.5	1.0	1.0	1.0	1.0	1.0
Construction	-	-	-	-	-	-	-
Total	3.5	5.0	7.0	8.0	8.5	9.0	9.0
Direct Personnel	20.0	24.0	28.0	32.0	35.0	38.0	38.0

11. International Cooperation in Nuclear Safety and Nonproliferation

Following the nuclear accident at Chornobyl in 1986 and the breakup of the Soviet Union in 1991, previously hidden problems of safety, security, and control for nuclear materials have become highly visible in the countries of the former Soviet Union (FSU). Many improvements in these areas are needed, in nuclear power plants, other nuclear facilities, and related national infrastructures, especially to counteract problems that arose from the fragmentation of central authority and the emergence of many independent states with their own safety and safeguards organizations. The United States and other industrialized nations, through the Group of Seven and the Group of Twenty-Four, have sponsored a number of cooperative programs aimed at helping the FSU countries and the countries of central and eastern Europe deal with these and related problems. Progress has been achieved, but very large problems remain that deserve attention from the best expertise available internationally.

Argonne proposes to establish programs of international cooperation in nuclear safety and nonproliferation. The near-term emphasis will be on problems in the FSU countries. However, growing use of nuclear technology in developing countries justifies concern about nuclear safety and materials security in those countries. Accordingly, this initiative also envisions eventual collaboration with developing countries, especially in the development of safety technology.

Argonne has been a worldwide leader in the development of nearly all phases of nuclear power since the late 1940s. The basic concepts and designs for many of the world's operational and advanced reactors were developed at the Laboratory. Argonne also has extensive experience in operating nuclear facilities and handling nuclear material. The Laboratory has unique expertise and capabilities to devote to international nuclear safety and nonproliferation.

Argonne is currently working on several international nuclear safety projects, including its management of the International Nuclear Safety Center (INSC) and its participation in the International Nuclear Safety Program. These activities currently focus on Russia, Kazakhstan, and Ukraine, but the INSC concept deserves expansion to other countries. Projects include the establishment of an international nuclear safety database, collaborative R&D on advanced safety concepts, and evaluation of safety issues for DOE (e.g., regarding the Chornobyl BN-350 reactors).

Current international Argonne programs in nonproliferation include the Reduced Enrichment for Research and Test Reactors (RERTR) program; coordination of material protection, control, and accountancy (MPC&A) activities in the non-Russian FSU republics; pilot projects to evaluate remote monitoring of nuclear materials; and technical assistance supporting the development, implementation, and enforcement of export controls and technology security programs.

In the safety area, Argonne has established the structure of its INSC program, but activities are severely constrained by limited funding. The present initiative would expand the technical scope of work under the INSC and the number of countries involved. Proposed for expansion is work on materials behavior, phenomena limiting plant life, large-scale safety experiments (both out-of-pile and in-pile), improved simulation exploiting advanced modeling and application of advanced computing technology, and support for emergency planning and response. International nuclear safety assistance is an ideal application of Argonne's established nuclear expertise.

Growth in Argonne's work on nonproliferation will target specific areas where the Laboratory has technical expertise or can make specific contributions. The work initially will focus on developing spin-off activities related to the Laboratory's established MPC&A and training programs in Kazakhstan and Ukraine and on accelerating the RERTR program for Russia. Argonne expertise is already being applied to enhancing the security of plutonium in the

blanket of the BN-350 fast reactor in Kazakhstan.

Like the existing programs, funding for extended programs in international nuclear safety is sought from DOE Nuclear Energy, Science and Technology (AF), and funding for programs in nonproliferation is sought from DOE Nonproliferation and National Security (GD). Resources required are summarized in Table IV.9.

Table IV.9 International Cooperation in Nuclear Safety and Nonproliferation
($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	9.4	14.4	17.0	17.0	17.0	17.0	17.0
Capital Equipment	0.4	0.5	0.6	0.6	0.6	0.6	0.6
Construction	-	-	-	-	-	-	-
Total	9.8	14.9	17.6	17.6	17.6	17.6	17.6
Direct Personnel	35.0	45.0	50.0	50.0	50.0	50.0	50.0

B. Programmatic Initiatives

The programmatic initiatives listed in Table IV.10 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 Chapter V.

Table IV.10 Programmatic Initiatives

Initiative	DOE Program	Page
Energy Research		
Argonne National Atmospheric Observatory	KP-02	69
ATLAS Detector at the LHC	KA-01 KA-03	74
MINOS Long-Baseline Detector	KA-01 KA-03	74
Fundamental Chemistry of Radioactive Waste	KC-03	84
Linear Accelerator Upgrade — Ultrafast-Pulse Radiolysis Facility	KC-03	84
Atomic Physics at Synchrotron Light Sources	KC-03	86
Energy Efficiency and Renewable Energy		
Urban Technology	EC	90
Fossil Energy		
Ion Transport Membranes for the Production of Synthesis Gas from Natural Gas	AB-05	99
Environment, Safety, and Health		
Assessment and Management of Risk	HA, EW, EX	108

V. Scientific and Technical Programs

Argonne conducts work for DOE's program secretarial offices, for several DOE contractors, and for a number of sponsors other than DOE. This chapter describes the Laboratory's ongoing scientific and technical programs for these sponsors, and it also describes the seven programmatic initiatives listed at the end of Chapter IV.

Total staffing for ongoing Argonne programs is projected to decline somewhat over the years covered in this plan, following construction of the Advanced Photon Source. Table V.1 summarizes present and projected levels of operating support by major category of sponsor. The resource requirements specified for programmatic initiatives in this section and for Laboratory initiatives in Chapter IV generally represent increments to the resource projections for ongoing programs presented here and in Chapter XII.

The Office of Energy Research and the Office of Nuclear Energy, Science and Technology will remain the largest sponsors of work at Argonne. Argonne work for sponsors other than DOE (excluding funding from the Nuclear Regulatory Commission) is projected at midyear to account for 12% of Laboratory support in FY 1996.

Table V.1 Major Program Summary
($ in millions BA operating funds;
% of total in italics)

Program	FY95	FY96	FY97
Nuclear Energy, Science and Technology	100.5 *21.1*	95.9 *21.2*	98.6 *20.6*
Energy Research	166.1 *34.9*	174.7 *38.7*	184.8 *38.7*
Energy Efficiency and Renewable Energy	18.6 *3.9*	20.4 *4.5*	29.5 *6.2*
Fossil Energy	6.4 *1.3*	5.1 *1.1*	5.4 *1.1*
Defense Programs	1.3 *0.3*	2.1 *0.5*	0.8 *0.2*
Nonproliferation and National Security	8.2 *1.7*	10.3 *2.3*	12.9 *2.7*
Environmental Management	70.1 *14.7*	55.9 *12.4*	57.5 *12.0*
Other DOE Assistant Secretarial Offices	15.5 *3.3*	8.2 *1.8*	9.5 *2.0*
Work for Other DOE Contractors	17.2 *3.6*	18.0 *4.0*	19.5 *4.1*
Transfer to Other DOE Contractors	(5.3) *(1.0)*	(3.0) *(0.6)*	(3.0) *(0.7)*
Work for Sponsors Other than DOE	77.0 *16.2*	63.7 *14.1*	62.6 *13.1*
Total Laboratory Operating Funding	475.6	451.3	478.1

A. DOE Programs

1. Nuclear Energy, Science and Technology

a. Overview

At the end of FY 1994, DOE decided to terminate the Integral Fast Reactor (IFR) program and the associated Actinide Recycle program. Termination included shutting down the Experimental Breeder Reactor-II (EBR-II) at the end of FY 1994. Activities associated with this termination of programs and facilities constitute one major element of Argonne's nuclear technology programs in FY 1996. The second major element comprises activities focused on the treatment of spent nuclear fuel, reactor and fuel cycle safety, and development of decontamination and decommissioning (D&D) technology.

b. Facility Shutdown and Program Termination

The highest priority among all termination activities is a timely and safe shutdown of

EBR-II. The reactor was officially shut down on September 30, 1994, after 30 years of operation. The continuing goal is to place EBR-II in an industrially and radiologically safe shutdown condition by the end of FY 1998, in preparation for transfer to the DOE Office of Environmental Management for ultimate decommissioning. This process involves removal and temporary storage of reactor fuel, removal and processing of sodium from the primary and secondary system, and then safe closure of the reactor system. In FY 1995 Argonne implemented the planning, documentation, approvals, and organizational adjustments required to safely shut down EBR-II. By the end of the year, 177 core driver subassemblies had been removed from the core (seven more than scheduled); unloading continued in FY 1996.

The EBR-II shutdown also includes treatment of discharged spent fuel. The EBR-II driver fuel contains highly enriched uranium even at discharge (53-75% uranium-235), raising concerns about *in situ* criticality upon disposal in a repository. The EBR-II spent fuel also contains reactive materials that may not be placed in a repository. Accordingly, EBR-II spent fuel must be treated to remove its high fissile content and reactive materials before permanent disposal in a repository. An electrometallurgical technique will be used for this treatment, employing the refurbished and reequipped Fuel Conditioning Facility (FCF).

Reactivation of the Sodium Processing Facility is a key element of the plan to shut down EBR-II. Constructed in the late 1980s to convert Fermi-1 sodium to sodium hydroxide, the facility will be modified to implement an additional processing step to produce sodium carbonate. The primary and secondary sodium from EBR-II can then be converted into a nonreactive low-level waste for storage in the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory. Required revisions and modifications of technical specifications are being performed, and the safety case for the Sodium Processing Facility is being developed. Within the overall facility, the existing sodium hydroxide facility is being modified, and a sodium carbonate facility is being added. Construction contracts for the sodium carbonate facility addition have been placed, and work was on schedule in early 1996. Construction of the overall facility is to be completed by the end of FY 1996.

Applications for required environmental permits had been completed or were under development in early 1996. The RCRA (Resource Conservation and Recovery Act) permit application for the Sodium Processing Facility was completed in June 1995; development of the RCRA permit application for closure of EBR-II reactor systems is a major ongoing activity. The state of Idaho permit to construct the Sodium Processing Facility has been approved, and work continues on the facility's application under the National Emission Standards for Hazardous Air Pollutants.

The main mission of the Fuel Manufacturing Facility is to fabricate dummy assemblies to replace the driver and blanket assemblies removed from EBR-II. Upon completion of this task, the facility will be placed and maintained in an industrially and radiologically safe shutdown condition, except for areas required to support other shutdown activities and continuing programs.

The Zero Power Physics Reactor, Transient Reactor Test Facility, and Argonne Fast Source Reactor are being placed and maintained in an industrially and radiologically safe shutdown condition. Although the reactors are being shut down, some or all of the facilities and the storage vault will continue to be used to support other activities for DOE-Environmental Management, such as development of the plasma hearth process and study of gas generation at the Waste Isolation Pilot Plant. The vault of the Zero Power Physics Reactor may be used for storage of products from treatment of EBR-II spent fuel.

The FCF and the Analytical Laboratory will play central roles in the treatment of EBR-II spent fuel. The FCF has been totally rebuilt to modern safety standards and provided with new processing equipment. In-cell qualification of all key equipment is complete. Underway are tests to optimize the operations parameters of the process equipment, using depleted uranium and unirradiated fuel pins. Depleted uranium

has been successfully recovered in the electro-refining process. The FCF is ready for a hot demonstration of electrometallurgical treatment of spent fuel from EBR-II. The environmental assessment for the facility had been rewritten and was awaiting final action in early 1996.

The Hot Fuel Examination Facility, along with the associated Neutron Radiography Reactor Facility, is a versatile, modern hot cell facility. It is being operated and maintained to support the fuel transfers and waste transfers associated with the shutdown of EBR-II, as well as to support the redirected program and other ongoing DOE-Environmental Management programs.

c. Nuclear Technology Programs

The DOE nuclear technology programs at Argonne now focus on issues and problems associated with the current generation of nuclear power plants both in the United States and worldwide, on incremental improvements to these plants, and on problems resulting from DOE's operation of research, prototype, and production reactors over several decades. Specific Argonne programs are addressing treatment of DOE spent nuclear fuel, reactor and fuel cycle safety (especially for Soviet-designed plants in Russia and Eastern Europe), and the development of D&D technology.

Argonne has initiated a major effort to adapt electrometallurgical technologies developed at the Laboratory to the conditioning of spent nuclear fuel from DOE reactors. A total of approximately 2,700 metric tons of spent nuclear fuel has accumulated within the DOE complex. This government-owned fuel was used in a variety of nuclear reactors, including reactors for the production of national defense materials, experimental and research reactors, and commercial reactors. This DOE spent fuel presents special problems that demand prompt attention. Arising from over 40 years of evolution in nuclear power, it reflects a wide diversity of fuel types, cladding materials, levels of enrichment in the fissile isotopes of the actinide elements, and degrees of chemical reactivity. Included in the DOE spent nuclear fuel inventory are fuels that have undergone serious degradation during storage, are highly enriched in fissile isotopes, are chemically reactive or contain reactive materials, and

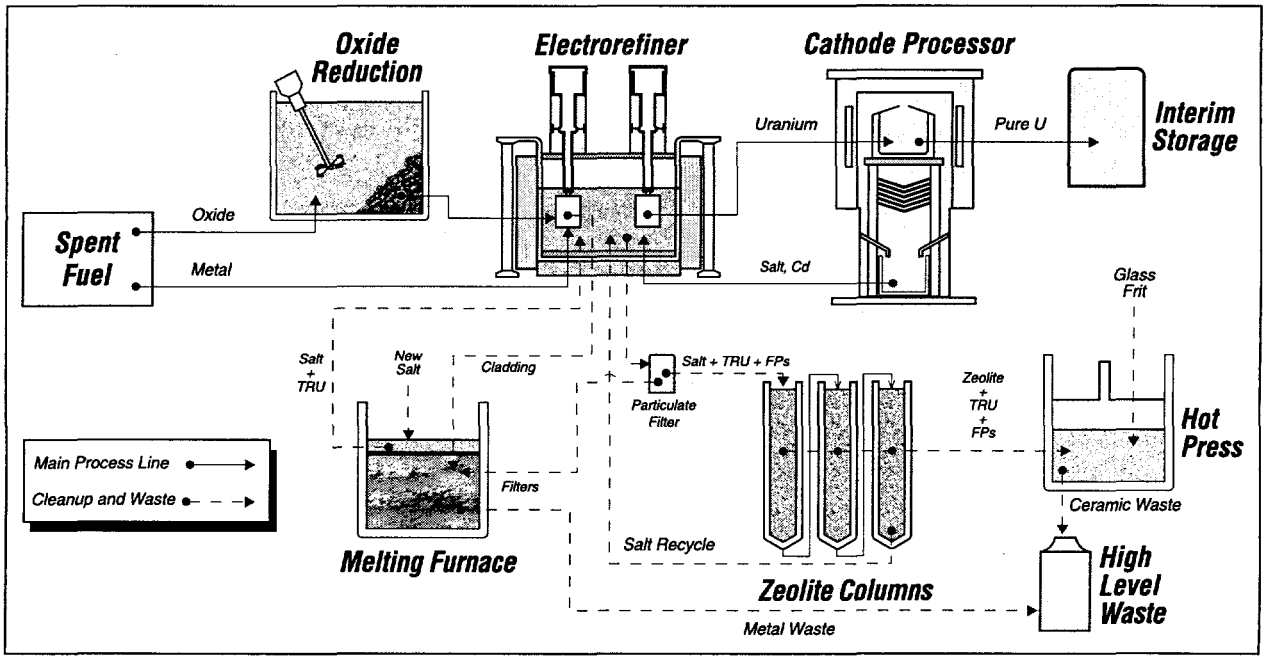


Figure V.1 Argonne's electrometallurgical technology is being adapted to treat spent fuel from the EBR-II reactor. The technology also has great potential for treating other DOE spent nuclear fuel types.

cannot be expected to retain their integrity or remain stable over an extended period of wet or dry storage.

Argonne's electrometallurgical treatment technique has great potential for application to the various types of DOE spent nuclear fuel, to enable ultimate disposal. This technique uses a simple, compact processing system that is both economical and technically sound and is applicable in its current stage of development to over 90% of the DOE spent fuel inventory. The technique will reduce waste volume, and, by implementing a common treatment approach at each site, it should reduce costs. Major subtasks in the program include treatment of metallic spent fuels, recovery and treatment of canister and storage basin sludge (from the Hanford Reservation), treatment of oxide spent fuel, a process for waste treatment, and waste form production and qualification. The overall goal is to complete the development of the electrometallurgical treatment technology for application to selected types of DOE spent nuclear fuel and to demonstrate the technology successfully in a timely fashion.

Argonne's research on conditioning spent fuel from DOE reactors has focused on increased throughput, oxide fuels, qualification of waste forms, and other issues. A concept for a high-throughput electrorefiner has been developed and demonstrated with N-Reactor fuel, showing effective treatment of the fuel. New laboratory facilities at Argonne-East, dedicated to developing waste forms, have produced a durable zeolite glass composite that was shown to meet established stability criteria for geologic disposal. Also demonstrated was a process for treating spent oxide fuels; a lithium reduction process was applied at large scale to oxide fuels.

Safety considerations continue to be important for the future of nuclear energy. DOE is developing programs to promote improvements in safety technology and in the international dissemination of safety information, with emphasis on the former Soviet Union and on Soviet-designed reactors elsewhere.

Argonne's work on international nuclear safety reached significant milestones in 1995. An International Nuclear Safety Center was established for DOE. An initial database at the Center, accessible through the Internet, already contains large amounts of information on design and safety analysis (including safety analysis methods) for U.S. and Russian Federation reactors. The intent is to include all available public information of this kind. Argonne is adapting its state-of-the-art methods of structural and safety analysis to Russian reactor designs. In addition, the Laboratory is measuring materials properties to support experiments by the Russian Federation on in-vessel retention of melted core materials. Other evaluations of safety issues for DOE have included reviewing safeguards against potential plutonium diversion at BN-350 and assessing possible replacements for the plutonium production reactors at Tomsk-7 and Krasnoyarsk-26. With colleagues from Ukraine and the European Community, Argonne engineers have actively participated in international work aimed at stabilizing the Chornobyl sarcophagus and, in the longer run, constructing a new shelter over the damaged reactor.

d. Other Nuclear Energy Programs

In addition to the nuclear technology programs discussed above, the DOE Office of Nuclear Energy, Science and Technology is supporting several other programs at Argonne.

Argonne has a major role in DOE's Advanced Reactor Severe Accident Program. Argonne personnel contribute to the effort to define, address, and resolve issues relating to severe accidents for advanced light-water reactors; the issues are identified internally or from Nuclear Regulatory Commission questions about safety. The Laboratory applies quantitative methods to evaluate the severity of accident consequences. Attention centers on the viability of vessel cooling using water to prevent an accident from breaching the confines of the reactor vessel. Key analyses address in-vessel melt progression, meltwater interaction, steam explosion energetics, vessel response to an internal steam explosion, and external cooling to prevent meltthrough of the vessel bottom head during a severe accident.

Argonne is developing a computerized model to help DOE manage a stockpile of over 500,000 metric tons of depleted uranium currently being stored as uranium hexafluoride in steel cylinders at various DOE sites. In its analysis of cylinder management, conversion of uranium hexafluoride to oxides or metal, and disposal options, the model projects risks to humans and the environment, as well as cost impacts. Argonne is also developing the programmatic environmental impact statement for DOE's long-term management of the material.

The DOE work in the area of space power and propulsion has declined for several years. Presently, Argonne supports DOE's program to develop a radioisotopic generator for missions of the National Aeronautics and Space Administration. The prospects for growth in work on space power and propulsion are not good, but the Laboratory plans to continue support for ongoing work and to contribute strongly to any future growth in this DOE program area.

Argonne supports DOE's Soviet-Designed Reactor Safety Program, which assists Russia, Ukraine, and Eastern European countries operating Soviet-designed reactors. Older Soviet-designed reactors do not meet Western safety standards and are a significant concern. The DOE program provides direct assistance to improve the safety of these plants and generally to improve the safety culture and infrastructure in recipient countries. Argonne provides technical support to DOE in plant safety evaluation and risk assessment, along with technical assistance to DOE and Russia in the development of generic off-site emergency preparedness systems for communities and regions near Russian nuclear power plants.

2. Energy Research

a. Overview

Argonne conducts work in fusion energy, biological and environmental research, high energy and nuclear physics, the basic energy sciences (which include materials sciences, chemical sciences, and engineering and geosciences), computational and technology research (which includes advanced energy projects, mathematics, and computer science), and the Laboratory Technology Research Program. In addition, the Laboratory supports the Basic Energy Sciences Advisory Committee and its panels and, through the University/DOE Laboratory Cooperative Program, promotes extensive interactions between Argonne and the academic community.

The Laboratory's role in the fusion energy program is R&D on fusion nuclear systems and studies of reactor design and systems. Argonne is the lead laboratory for the DOE blanket technology program.

Biological and environmental research at Argonne seeks to explore fundamental processes and to apply and develop methodologies for determining health and environmental effects of energy-related toxicants. The programs include basic mechanistic studies dealing with primary physical and chemical interactions of molecules at short time scales, long-term determinations of chronic biological and environmental effects, transport and deposition of trace substances, and the environmental effects of energy use.

Research and technology at Argonne in high energy physics include theoretical and experimental investigations, usually involving use of particle accelerators, that advance understanding of the structure of matter and energy at the most fundamental level. Also included are R&D on new accelerator concepts and on new detector technology. The Laboratory's nuclear physics program pursues comprehensive understanding of all aspects of the structure, dynamics, and interactions of atomic nuclei. This program also develops, operates, and uses accelerators such as the superconducting Argonne Tandem-Linac Accelerator System (ATLAS), a national user facility for studying heavy-ion reactions that has been upgraded to provide ion beams for all elements up to uranium.

Research in materials sciences at Argonne comprehensively addresses the properties of condensed phases and the scientific bases for

new materials. A continuing mission is the development, operation, and use of state-of-the-art collaborative research facilities, such as the Electron Microscopy Center for Materials Research and the Intense Pulsed Neutron Source (IPNS). In preparation for vast scientific opportunities at the Advanced Photon Source (APS), substantial growth in synchrotron-based programs is underway.

The Laboratory is now completing construction of the APS, which will be used for materials research and many other applications as well, across an extraordinarily broad range from basic science to developmental engineering. Like earlier Argonne facilities, the APS will serve users from universities, industry, and national laboratories.

Research in chemical sciences at Argonne encompasses a broad spectrum of fundamental investigations into atomic and molecular phenomena. There are formal programs in reactive intermediates in condensed phases, electron transfer in chemical systems, photosynthesis and photochemical energy conversion, chemical dynamics in the gas phase, metal cluster chemistry, the fundamental chemistry of coal, the separation science and chemistry of the heavy elements, atomic physics, fluid catalysis, and lithium batteries.

Argonne's research in mathematics and computer science focuses on designing methods, algorithms, and tools for large-scale numerical and symbolic computations. Mathematicians and computer scientists collaborate with computational scientists on software and methods for applications such as global climate modeling, computational chemistry, computational biophysics, and materials science. Research includes development of new algorithms and adaptation of both production and state-of-the-art research codes to exploit advanced computer architectures and incorporate scientific visualization graphics. This work emphasizes cooperation with various scientific organizations at Argonne and with universities and industrial firms. The Laboratory's High-Performance Computing Research Facility offers the massively parallel IBM SP computer for large-scale calculations.

In the geosciences, Argonne studies the atomic-scale processes occurring at mineral-fluid interfaces.

Five initiatives proposed for support by the Office of Energy Research are designated as Laboratory initiatives and are described in Chapter IV: Center for Collaborative Science and Technology, Mechanistic Biology (KP), Exotic Beam Facility (KB-02), APS Beamlines (KC-02), and Advanced Pulsed Neutron Source Technology Development. (Related DOE programs from which funding is sought are indicated above in parentheses.) Argonne is proposing a number of programmatic initiatives, which are typically more narrow in scope and impact. They are described as part of the programmatic discussions that follow. (See Table IV.10 for a complete list of Argonne's programmatic initiatives.)

b. Magnetic Fusion (AT)

Argonne's work on the development and technology of magnetic fusion includes studies of fusion nuclear technology, fusion reactor materials, and reactor designs. The work on fusion nuclear technology concentrates on the first-wall blanket and shield systems. The materials research focuses on advanced structural and blanket materials. The design effort emphasizes nuclear systems for the International Thermonuclear Experimental Reactor (ITER) and design of advanced tokamak power reactors. ITER is a joint effort of the European Community, Japan, Russia, and the United States.

Argonne plays a lead role for the part of the ITER study that addresses nuclear systems. The work includes designing the first-wall/blanket/shield and the plasma facing components and defining the nuclear test program and test modules. This design work includes assessment of materials databases; performance of neutronic, stress, and thermal-hydraulic analyses; and investigation of plasma physics issues related to plasma-wall interactions. Overall, Argonne is a major participant in the ITER design team.

Argonne's studies of blanket technology for magnetic fusion include both liquid metal and ceramic breeder blankets. Argonne investigates phenomena related to magnetohydrodynamic (MHD) aspects of liquid metal blankets, properties of ceramic breeder materials and beryllium, insulators for liquid metal blankets, breeder neutronics, small blanket module tests, and transient electromagnetic effects. Liquid metal MHD is studied in the Argonne Liquid Metal Experiment (ALEX) facility. Current tests are examining test sections composed of vanadium alloys to which an insulator coating has been applied. The insulator coating greatly reduces the MHD pressure drop, enhancing the capabilities of liquid metal systems. ALEX was recently upgraded to lithium operation for these tests.

The Laboratory's work on blanket technology for ITER includes a subcontract with an industrial consortium led by McDonnell Douglas Company.

Argonne's research on fusion materials focuses on first-wall/blanket materials. Primary emphasis is on developing vanadium alloys, studying corrosion and compatibility, developing lithium ceramics for producing tritium, and designing a 14-MeV neutron source for materials testing. The research on vanadium alloys currently focuses on developing baseline data on mechanical properties and investigating the effects of neutron irradiation on mechanical properties. In collaboration with Japanese researchers, Argonne has developed a new method for investigating the effects of higher, fusion-relevant rates of helium generation in alloys during fission reactor irradiations. Work on corrosion and compatibility focuses on vanadium alloys in liquid lithium. Argonne continues to develop lithium ceramics for tritium production. This work will emphasize modeling and experimental studies of thermodynamic and physical properties and of the transport properties of hydrogen (tritium). Argonne is contributing to the development of an accelerator-based high-energy (14-MeV) intense neutron source for studies of fusion materials.

In studies on advanced reactors, Argonne continues to collaborate with the University of California at Los Angeles on the ARIES/DEMO study. Argonne's work in this collaboration focuses on developing advanced blankets and impurity control systems that emphasize simplified designs and inherent safety, investigating current profile control to enhance plasma stability, and developing associated current drive concepts.

c. Biological and Environmental Research (KP)

Argonne's human health research program encompasses studies in analytical technology research (KP-01), environmental research (KP-02), health effects research (KP-03), general life sciences (KP-04), and carbon dioxide research (KP-05). These studies include investigations in the general areas of molecular and cellular biology, DNA sequencing, radiation biology, biophysics, detector technology, atmospheric science, microbiology, ecology, and statistical studies of health effects on animal populations.

Environmental Research (KP-02)

Argonne's environmental research encompasses atmospheric studies and measurements and investigations of fundamental ecosystem adjustment and subsurface geochemical processes.

In atmospheric studies, the Laboratory investigates the transport and dispersive properties of the lower atmosphere with ground-based, remote-sensing equipment such as Doppler acoustic sounders, radars, and laser anemometers and with direct-sensing devices deployed at the surface or carried aloft by balloons. Mathematical descriptions of transport and diffusion are developed and tested against experimental data.

Dry deposition refers to the delivery of trace atmospheric substances to the surface without the aid of precipitation. For DOE's Atmospheric Chemistry Program (ACP), Argonne is conducting experimental, theoretical, and modeling studies on the air-surface exchange of energy-related trace substances, especially

sulfur oxides, nitrogen oxides, ozone, and organic substances. Field studies use micrometeorological techniques and environmental enclosures. The Laboratory is developing models for use in regional and global studies that require estimates of dose to the surface or atmospheric mass budgets.

Argonne contributes to experimental investigations of the chemical and physical processes associated with the atmospheric sources and the fates of trace chemicals. The Laboratory studies the effects of energy-related trace chemicals on the photochemistry of the atmosphere and the long-range transport of these substances and their transformation products to continental receptor areas.

Through field studies, laboratory modeling, and development of analytical techniques, Argonne chemists are examining the effects of organic oxidants (such as peroxyacyl nitrates, organic peracids, and organic hydroperoxides) on gaseous, aqueous, and aerosol species in the atmosphere. State-of-the-art spectroscopic systems are used to investigate the effects of ultraviolet-B radiation and longwave radiation on organic oxidants. The goal is to elucidate the roles of organic compounds in atmospheric chemistry in urban areas and on regional and global scales.

Argonne is studying daily temporal and spatial variabilities in column ozone over portions of the Northern and Southern Hemispheres for the years 1979-1992. This work for the ACP involves statistical analysis of comprehensive data obtained by the Total Ozone Mapping Spectrometer carried on the Nimbus 7 satellite. Central questions include the frequency of extreme total ozone events, their time trends, and the mechanisms generating the extremes and their variability.

Argonne staff lead the scientific coordination for the ACP. The ACP scientific coordinator works to enhance overall scientific progress with researchers at 8 DOE laboratories and approximately 20 universities and non-DOE laboratories. The project also supports activities of the North American Research Strategy for Ozone (NARSTO) program coordinator, who is employed by a private company. The NARSTO program is a Canadian-U.S.-Mexican effort to provide the scientific and engineering basis for policy-making related to tropospheric ozone.

Argonne staff, in collaboration with other investigators in the Subsurface Science Program, are investigating the interactions of plutonium-organic contaminant mixtures in the subsurface. This work uses a combination of techniques, including high-sensitivity laser spectroscopy, absorption spectrometry, and potentiometry. Experiments that extend the plutonium-organic studies to include microbial interactions are being conducted in collaboration with three other national laboratories: Pacific Northwest, Brookhaven, and Lawrence Berkeley. Results will lead to an improved understanding of co-contaminant interactions in the subsurface and will provide a basis for developing innovative concepts for *in situ* remediation.

For the Microbial Origins Subprogram of the Subsurface Science Program, Argonne is conducting geologic studies of field sites in Colorado, Virginia, and Delaware, in collaboration with Pacific Northwest National Laboratory, Sandia National Laboratories, Princeton University, and Old Dominion University. The purpose is to collect deep microbiological samples and evaluate microbial transport in the subsurface. Argonne expects to establish criteria that define geologic environments conducive to bacterial isolation, transportation, and survival in the deep subsurface. This work will contribute to an understanding of geologic controls on microbial risk assessment and deep bioremediation at DOE sites.

An Argonne laboratory study supported by the Program for Ecosystem Research is investigating the mechanisms that control mycorrhizal symbiosis in different types of grasses under a changing global environment. The objective is to determine whether a primary mechanism controlling the mycorrhizal association provides the balance between photosynthate supply to the roots and a host's need for nutrients. In addition, a model-based study is assessing the potential effects of climate change on forest ecosystems in the United States. The aim is to make models of forest growth more realistic by accounting for the tolerance of trees

to climate variability and for the resistance of vegetation to change.

Initiative: Argonne National Atmospheric Observatory

Improving the accuracy of short-term and medium-term weather forecasts — for periods of hours to months — would save billions of dollars and hundreds of lives annually. However, improving forecasts depends on obtaining 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. Accomplishing this challenging task in a way that provides open access for the broad scientific community can best be accomplished by a national laboratory.

Argonne proposes to build on its existing capabilities in atmospheric science, remote sensing, advanced computation, information processing, and facility management to develop an Argonne National Atmospheric Observatory for the study of atmospheric phenomena. The overall objective is to make 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 research.

Like other large national research facilities, the Argonne National Atmospheric Observatory will provide 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 proposed or support its long-term, continuous use, but both industry and academia will benefit greatly from its availability.

The Argonne National Atmospheric Observatory will be designed so that the basic measurements obtained are readily available to all interested scientists for their own research. This approach will facilitate the seamless integration of fundamental studies with mission-driven research. Active participation of national laboratory scientists will assure advancement across the entire relevant science and technology base.

The atmospheric research to be conducted will benefit the nation by promoting the effective and environmentally protective production and use of energy. This research will also provide benefits in the areas of defense, agriculture, water resource management, mitigation and public safety relating to natural disasters, and safe and efficient aviation and other transportation.

The schedule for developing the Argonne National Atmospheric Observatory is ambitious. Conceptual planning and definition of initial scientific approaches were completed in 1995. A prototype user facility, focused on studies of the planetary boundary layer, will be developed in southern Kansas (within the Cloud and Radiation Testbed [CART] site of the DOE Atmospheric Radiation Measurement Program) by the end of 1997. Integration of the prototype facility with the facilities of the larger CART site will continue through 2002. Funding is sought from the Biological and Environmental Research (KP) program. Resources required are summarized in Table V.2.

An environmental assessment for the entire CART site (DOE/EA-0680) was submitted in March 1992, and a finding of no significant impact was issued in June 1992. The proposed work is not expected to differ significantly in

Table V.2 Argonne National Atmospheric Observatory ($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	0.8	1.2	1.2	1.7	2.1	2.9	2.9
Capital Equipment	0.6	0.3	0.1	0.1	0.2	0.5	0.5
Construction	-	-	-	-	-	-	-
Total	1.4	1.5	1.3	1.8	2.3	3.4	3.4
Direct Personnel	4.0	6.0	6.0	7.5	10.0	15.0	15.0

environmental impact from the tasks reviewed in 1992.

Health Effects Research (KP-03)

Argonne's research on health effects extends from statistical studies on animal populations to investigations in cellular and molecular biology. The central question is how radiation and chemicals affect human health. These studies focus primarily, but not exclusively, on gene expression and structure-function relationships in critical cellular proteins, as well as on cancer-related questions.

Argonne's statistical studies involve evaluating (1) dose-response relationships from comparative interspecies studies of radiation exposure and (2) the risk of subsequent pathologies. Databases from studies of life shortening and tumor induction in rodents and beagles are analyzed to develop models for extrapolation to health hazards in humans.

A study of the molecular effects of radiation is seeking to identify the nature of induced cellular responses, by investigating the mechanisms of the early transcriptional events accompanying radiation exposure and elucidating the role of these events in post-irradiation viability of cells, malignant transformation, and DNA repair. Sensitive assays for gene expression using technology provided by Argonne's genome program (discussed below) have been developed. A related project examines the molecular mechanisms underlying radiation-induced lung tumors and lymphomas, focusing on the effects of deletions or mutations in oncogenes.

Argonne's protein mapping group is using two-dimensional gel electrophoresis (2DE) to analyze protein expression in both normal and challenged mammalian cells. Relational databases for data on mouse and human proteins are being built. These databases include information on the relative positions of proteins in 2DE patterns, subcellular location, identification, and changes in abundance or 2DE position in response to altered cellular conditions. Through identification of specific proteins, the molecular mechanisms that lead to observed protein changes can be understood.

Studies on the control of growth and differentiation in human cells seek to define molecular processes that govern replication, malignant transformation, differentiation, and programmed cell death (apoptosis) in various human cell types and tissues. Critical gene products — such as growth-modulating factors, protein kinases and phosphatases, adhesion molecules, and related proteins — are being characterized and tested for their function and role in signal transduction processes that initiate these events. A number of these proteins (including MRP8 and MRP14, two growth-inhibiting peptides, and inosine monophosphate dehydrogenase, a growth-controlling enzyme) have been expressed in bacterial systems and are being crystallized for structure-function analyses. Results from these studies promise better understanding of the proteins' structures and their roles in cellular replication, malignant transformation, differentiation, and apoptosis.

General Life Sciences (KP-04)

Argonne's studies in the general life sciences include work on human genome sequencing, investigations in structural biology, and biophysical and biochemical characterizations of the effects on living systems of energy-related toxicants.

Biophysical studies investigate relationships between the structure and function of proteins and other large biological molecules. X-ray crystallography, computational modeling and simulation, gel filtration chromatography, and other biophysical methods are used to analyze protein structures and their interactions with small ligands and with other proteins. Structural studies of antibodies, photosynthetic reaction centers, enzymes, and chaperonins elucidate their functional attributes. Site-specific mutagenesis of immunoglobulin light chains and the photosynthetic reaction center complex provides insight into alterations in function caused by single amino acid changes and allows testing of predicted relationships between structure and function.

Argonne is building and will operate a national user facility for structural biology at the APS. The Structural Biology Center (see

Section IV.A.4) will use one sector of the APS for diffraction studies of large biological molecules. (Each APS sector consists of an insertion device X-ray source and its adjacent bending magnet X-ray source.) A related project is developing an ultrafast detector for protein crystallography at synchrotron X-ray sources. This detector is based on a charge-coupled device and can be used at existing synchrotron sources as well as at the APS.

Argonne has begun a program to study the cellular and molecular biology of organisms living at extremely high temperatures — up to (or even slightly above) the boiling point of water. These so-called hyperthermophiles belong to a primitive group known as archaea. The Laboratory is exploring the basis for the extreme thermostability of their proteins and seeking potential uses for these molecules in biotechnology, bioremediation, and medicine. Also of interest are the mechanisms by which proteins are folded. A particular focus is a group of proteins known as heat shock proteins, which are found in all organisms and have been implicated in fundamental cellular processes in

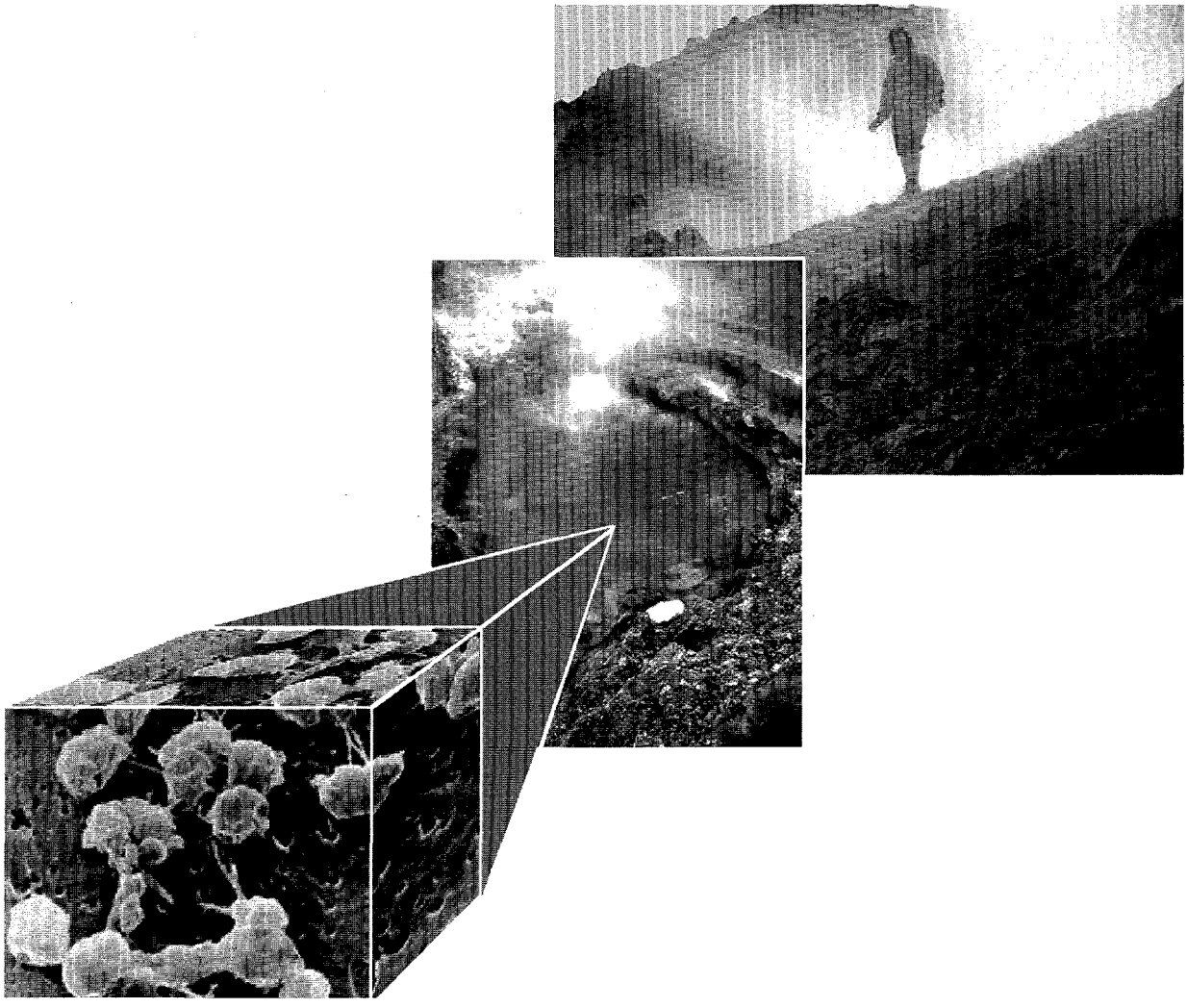


Figure V.2 An Argonne biologist traveled to Iceland to collect hyperthermophilic organisms in hot springs. These organisms, living in near-boiling water, are cultivated at the Laboratory to study the basis for their stable enzymes, which have potential use in biotechnology.

all organisms and in autoimmune diseases in humans.

In Argonne's genome program, work on developing the method of sequencing by hybridization on oligonucleotide microchips has established its practical validity and its potential for increasing the speed of DNA sequencing by orders of magnitude. Current efforts aim toward a production-scale laboratory capable of sequencing one million base pairs per day. Development of microchips for diagnosis and analysis in medicine, biology, and biotechnology is also underway.

Carbon Dioxide Research (KP-05)

Argonne participates in DOE's Atmospheric Radiation Measurement (ARM) Program by establishing field sites for scientific research, conducting specialized research projects, and supporting development of new research directions. The field sites are designed for experiments on solar and infrared radiative transfer and on the atmospheric properties that influence climatologically significant energy flows. Parameterizations will be developed for general circulation models and related models, to improve substantially their accuracy in predicting climate change. To sample important spatial and temporal variations in atmospheric conditions, at least three fixed field sites will be required.

For the ARM Program, Argonne leads efforts on instrumentation of the field sites, the data communication and management associated with that instrumentation, and site operations at the first site established. In specialized research, Argonne conducts experiments and develops parameterizations on the surface energy balance and other surface properties, to provide adequate descriptions of surface boundary conditions for large-scale models. The experiments rely on micrometeorological observations and observations of the atmospheric boundary layer, which are obtained by using both ground-based remote sensing and surface stations to measure air-surface exchange rates. To aid in the development of new research directions, workshops are conducted with leading scientists who are knowledgeable in global climatological processes, satellite observational techniques, and unmanned aircraft technology.

For the ARM Program's unmanned aerospace vehicle (UAV) project, Argonne is using data from satellites and surface observations to characterize the spatial variabilities of upwelling solar and infrared fluxes above the ARM field site in Kansas and Oklahoma. Resulting descriptions of surface optical characteristics will be used by ARM researchers to determine relationships between surface features and measurements of vertical radiative flux made from UAVs in the middle and lower atmosphere.

Argonne participates in the Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP) program through membership in a working group that includes the National Center for Atmospheric Research and Oak Ridge National Laboratory. Argonne researchers have released a parallel version of the Community Climate Model 2 and have completed the first version of a coupled atmosphere-ocean model.

For the Global Change Assessment Research Program, the Laboratory is working with the National Center for Atmospheric Research to study climate surprises and their incorporation into integrated assessment models.

For the Terrestrial Carbon Processes Program, Argonne is investigating processes involved in the storage and turnover of carbon in soil. An understanding of soil carbon dynamics is needed to determine the potential strength of terrestrial ecosystems as carbon sinks and to predict the roles of ecosystems in the global carbon cycle. Because organic matter incorporated into soil aggregates is physically protected from decomposition, the Laboratory is using conceptual models of aggregate formation, stabilization, and degradation as the basis for identifying and isolating measurable carbon pools with significant functional relationships to soil carbon dynamics. Laboratory studies are being conducted on samples from field experiments to determine whether the characteristics of these measurable carbon pools are affected

by elevated atmospheric concentrations of carbon dioxide.

Argonne is providing temporary staff support to the Committee on Environment and Natural Resources Research of the National Science and Technology Council. The work includes reviewing national and international R&D programs, assisting with planning and coordination of R&D programs, identifying relevant R&D needs, and providing advice and recommendations on national programs to assess human interactions with the global environment.

d. High Energy Physics Research (KA-01)

High energy physicists use complex detector facilities to advance knowledge of the fundamental laws of nature. These facilities typically require substantial engineering efforts and collaboration among many institutions. Argonne scientists continue to play special roles in the design and use of such research facilities, starting with the development of imaginative physics perspectives. The Laboratory also provides specialized capabilities in technology, engineering, and project management.

Argonne's accelerator-based research programs include the Collider Detector at Fermilab (CDF); the ZEUS detector at the electron-proton colliding beam facility (HERA), now in operation at the Deutsche Elektronen Synchrotron (DESY) Laboratory in Hamburg, Germany; polarized proton experiments at CEN Saclay in France and at Brookhaven National Laboratory; and the ATLAS (A Toroidal LHC ApparatuS) detector at the Large Hadron Collider (LHC) at the CERN laboratory in Geneva, Switzerland. (This detector is not related to the Argonne Tandem-Linac Accelerator System, also known as ATLAS.)

Argonne, in collaboration with eight U.S. universities, provided the central calorimetry for the ZEUS detector at the HERA collider and is now using the detector to study electron-proton collider physics. Collection of ZEUS data from electron-proton collisions began in 1992 with participation by resident Argonne physicists. Most have now returned to the Laboratory and are analyzing data, particularly for proton structure and function and for diffractive events. During the past year, Argonne researchers have commissioned in ZEUS an advanced trigger system for use with a new small-angle, rear-tracking detector designed to permit measurement of scattered electrons at very small q^2 values. The DESY Physics Review Committee has approved a proposal by Argonne, in collaboration with U.S. universities, to add a presampler system to the detector's barrel calorimeter. The presampler will improve energy measurements in regions where inactive material precedes the calorimeter.

The current highly successful CDF program at Fermilab produced data that led to the first observation of the "top" quark, a key element of fundamental particle physics. Using data gathered between 1992 and February 1996, the CDF program is seeking to refine measurements of the mass and other properties of the top quark. The improved capabilities of the Fermilab collider make this goal feasible. Earlier, CDF provided the first precise measurements of the masses of the Z° and W bosons, two other key elementary particles that underlie the "weak" nuclear forces in nature.

Argonne's long-standing expertise in the use of spin as a probe of elementary particle interactions will be applied to studies using colliding beams of polarized protons at Brookhaven's RHIC (Relativistic Heavy Ion Collider) accelerator. Argonne and others are designing and developing an electromagnetic calorimeter for the STAR detector at RHIC. An experiment is underway to test the source of polarized protons at the Alternating Gradient Synchrotron at Brookhaven.

Not all research in high energy physics involves experiments using particle accelerators. The Soudan 2 iron plate, gas calorimeter detector is now taking data in a laboratory deep underground in northern Minnesota. Installation of detector modules for Soudan 2, fabricated by Argonne and Rutherford Laboratory, ended with completion of 930 tons of detector in FY 1993. Data collection will continue through FY 1998. The power of the detector to search for unusual nucleon decay modes, monopoles, and neutrino oscillations from cosmic ray event sources will

increase as operations proceed. While it conducts the lengthy search for nucleon decay, the collaboration is also using the detector to measure the ratio υ_μ/υ_e for neutrinos produced in the atmosphere by cosmic rays. Data from Soudan 2 have confirmed previous experimental measurements of this ratio, which appears to be anomalous. One interpretation of the anomalous ratio is that neutrinos have mass and are able to "oscillate" into other species of neutrinos. Confirmation of this interpretation would have far-reaching implications for both particle physics and cosmology. As a result, Argonne has led the formation of a new collaboration ("MINOS"), whose proposal to aim neutrinos from Fermilab toward a new detector in the Soudan mine was recently approved.

Argonne's theoretical research aims at establishing models of strong interaction phenomena and applying the models to experimental data. Current activities include (1) calculations leading to new experimental tests of perturbative quantum chromodynamics (QCD) and to systematic understanding of scale-breaking phenomena such as inverse power, higher twist effects, nuclear dependent effects in short-distance processes, spin effects at high energy, and the phenomenology of high-energy collider experiments and (2) fundamental studies of hadronic diffraction scattering in the context of QCD.

The Laboratory's program of numerical computation to probe the nonperturbative aspects of QCD through lattice gauge theory calculations is exploring a new regime, the dynamical fermion lattice QCD computation of the hadron mass spectrum.

Initiative: ATLAS Detector at the LHC

The mechanism of electroweak symmetry breaking remains one of the most fundamental questions facing particle physics. Following cancellation of the Superconducting Super Collider (SSC), the LHC project at CERN — approved by the CERN council in December 1994 — is the only planned accelerator where this central topic can be studied, although its energy will be lower than that planned for the SSC. Argonne has formed a collaboration of university groups and Argonne staff members to work on the barrel hadronic calorimeter and the trigger system for the ATLAS ("A Toroidal LHC ApparatuS") detector at the LHC. Together with its university collaborators, Argonne proposes to build and instrument one of three major subsections of the hadronic calorimeter and to build the key Level 2 supervisor and region-of-interest builder trigger systems. The calorimeter will use scintillating-tile technology that was developed for the SSC, while the trigger systems will build on Argonne's work for the ZEUS detector.

Resources required for work on the ATLAS at the LHC are summarized in Table V.3. Funding is sought from the High Energy Physics Program (KA-01 and KA-03).

Table V.3 ATLAS Detector at the LHC
($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	0.2	0.8	1.0	1.1	1.0	0.8	0.8
Capital Equipment	0.3	0.5	0.5	0.4	0.2	0.2	0.2
Construction	-	-	-	-	-	-	-
Total	0.5	1.3	1.5	1.5	1.2	1.0	1.0
Direct Personnel	1.5	6.1	7.1	8.5	7.5	6.0	6.0

Initiative: MINOS Long-Baseline Detector

The nature and properties of the fundamental fermions (six quarks and six leptons) are presently under intense scrutiny in high energy physics research. Among the questions of greatest interest are the masses of the three neutrino species and their possible mixing. Although all observations so far are consistent with zero masses for all neutrinos, that answer seems unlikely on theoretical grounds. Moreover, a number of experiments have produced anomalous results that could be explained by finite neutrino masses, by quantum mechanical mixing between the three types of neutrinos, or by both. For example, measurements of atmospheric neutrinos — including results from Argonne's Soudan 2 detector — indicate that the ratio of muon-type neutrinos to electron-type neutrinos may change

after their creation in cosmic ray collisions high in Earth's atmosphere.

The MINOS detector will make a highly sensitive search for oscillations of neutrinos from one type into another, by detecting neutrinos from Fermilab's new main injector after they have traveled 730 kilometers to the Tower-Soudan mine, the present home of the Soudan 2 detector. Argonne is providing leadership in several areas of development for the experiment. Argonne also plans to build much of the expanse of tracking detectors that are sandwiched between the 10 tons of magnetized steel plates constituting the detector. Argonne is also designing and constructing the steel plates.

Resources required for design and construction of the MINOS detector are summarized in Table V.4. Funding is sought from the High Energy Physics Program (KA-01 and KA-03).

Table V.4 MINOS Long-Baseline Detector
($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	0.5	0.7	1.0	1.1	1.1	0.8	0.8
Capital Equipment	0.2	0.3	0.6	1.0	1.0	0.6	0.4
Construction	-	-	-	-	-	-	-
Total	0.7	1.0	1.6	2.1	2.1	1.4	1.2
Direct Personnel	4.0	5.0	8.0	8.0	8.0	6.0	6.0

e. High Energy Physics Technology (KA-03)

Experimental facilities, apparatus, and techniques are needed for particle physics research. Argonne's program in this area includes work on particle detectors and accelerator R&D. The Argonne Wakefield Accelerator is currently being designed and constructed to demonstrate the feasibility of accelerating electron bunches to 1 GeV, with gradients exceeding 100 MeV/m, by means of intense preceding bunches of electrons with lower energy (i.e., two-beam acceleration). An intense, short-pulse, laser-driven electron gun has been developed to provide the intense driver beams.

Argonne's development of advanced detectors focuses on calorimetry and gas trackers. In calorimetry, the Laboratory is continuing to develop the technology of scintillator tiles read out by wavelength-shifting fibers. A prototype calorimeter using this advanced technique is being prepared for the ATLAS detector at LHC. Optimization of wire tracking chambers is underway for both the MINOS and CDF experiments. Particular attention is being given to the gases employed, both to enhance the lifetime of the detector in a radiation environment and to minimize flammability.

f. Nuclear Physics (KB)

Argonne plays a major role in U.S. research in nuclear physics. The Laboratory's program focuses on (1) low energy heavy-ion physics; (2) medium energy nuclear physics, which emphasizes the use of lepton beams (at Fermilab, the Thomas Jefferson National Accelerator Facility [TJNAF], and the Deutsche Elektronen Synchrotron [DESY]) as probes into the nuclear medium; and (3) nuclear theory, which focuses on developing fundamental understanding of nuclear dynamics and subnucleonic particles in the nucleus. The experimental work in heavy-ion physics is largely performed at ATLAS (the Argonne Tandem-Linac Accelerator System). A designated national user facility, ATLAS is based on superconducting radio frequency technology developed at Argonne. The accelerator was recently upgraded to provide ion beams for all elements up to uranium. In conjunction with ATLAS, Argonne has a leading program in accelerator development.

Medium Energy Nuclear Physics (KB-01)

Argonne's research in medium energy physics promotes understanding of the properties of nuclear matter by studying the fundamental interactions of nuclear constituents and the manner in which they are modified in the nuclear medium. The principal goal of this research is to understand the role of the quark-gluon structure of nucleons in shaping the character of nuclear forces. Argonne scientists

meet this goal by leading and collaborating in large research projects at major national and international facilities.

Argonne has made a major commitment to participate in research at TJNAF in Virginia. Laboratory staff already have a major presence in the TJNAF program. They have completed construction of a broad-purpose short-orbit spectrometer that is generally available to users at TJNAF. Initial research operations are predominantly in TJNAF's Hall C, where the Argonne group has focused its efforts. Of 12 proposals approved for the initial research program in Hall C, 4 are represented by spokesmen from Argonne, 1 has an Argonne cospokesman, and 2 others have Argonne collaborators. An additional Argonne proposal has been approved, contingent on demonstrating the feasibility of a new tritium target design that is under development at the Laboratory.

A substantial portion of Argonne's work in medium energy physics has been devoted to developing a new target technology for studying elastic electron-deuteron scattering to very high momentum transfer in a collaboration between Argonne and a group of Soviet physicists at the Institute of Nuclear Physics in Novosibirsk. Measurements now underway at Novosibirsk, at the 2.5-GeV VEPP-III electron storage ring, are entering their third and final phase. The program at Novosibirsk has provided a proof of principle for a broad U.S.-European experiment, titled HERMES, to study the spin structure of the nucleon by using internal polarized hydrogen, deuterium, and helium targets at the HERA electron storage ring. Argonne has primary responsibility for the particle identification systems in the HERMES particle spectrometer.

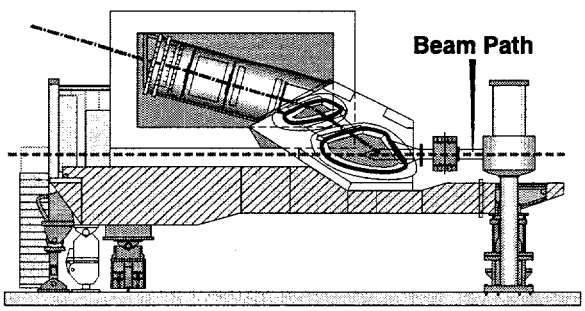


Figure V.3 The first experiment at the Thomas Jefferson National Accelerator Facility was conducted on the Short Orbit Spectrometer, shown here in a cutaway view. Argonne staff were responsible for the design and construction of the instrument, and a Laboratory physicist led the consortium conducting the initial experiment, which seeks to determine laws governing the motion of protons through atomic nuclei.

Experiments at Fermilab use the highest-energy lepton and hadron probes to measure directly the quark distributions of nuclei. Following measurements of deep inelastic scattering of muons from nuclei, new measurements of muon pair production in proton reactions will concentrate on the properties of the sea of anti-quarks that exist in the proton.

Heavy-Ion Nuclear Physics (KB-02)

Heavy-ion nuclear physics at Argonne combines a variety of activities, including research using ATLAS, operation of ATLAS, assistance to outside ATLAS users, development and improvement of ATLAS's experimental system and relevant experimental techniques, and development of new technology for superconducting linacs that will lead to continuing improvements in the ATLAS facility.

Heavy-ion research using ATLAS constitutes the major program in Argonne's Physics Division. The aim of the program is to study the behavior of nuclei under carefully selected conditions. Unique features of the ATLAS facility include the ability to generate precise beams of heavy ions with excellent energy and time resolution and easy variability of beam energies. These features permit a wide range of research investigating relationships between nuclear structure and dynamics. Of particular interest is the study of rapidly rotating nuclei. Argonne researchers pioneered investigations of very deformed nuclei in the heavy-mass region.

ATLAS is a national user facility, attracting physicists from many U.S. and foreign institutions. Its user group includes members from over 80 institutions. Outside users, assisted by a liaison physicist, are involved in more than 90%

of all experiments. A program advisory committee allocates running time among proposed experiments.

Argonne continues to investigate general aspects of superconducting technology for accelerating heavy ions. The choice of work is guided primarily by questions about the technology of ATLAS, especially ATLAS's new positive-ion injector. Most of this work addresses superconducting accelerating structures, electron-cyclotron-resonance heavy-ion sources, and time-of-flight technology for pulsed beams. Argonne has extended this work to include investigations into certain basic properties of radio-frequency superconductivity. Emphasis will be on the low-frequency range that has special importance for low-velocity accelerating structures. Results are expected to be of interest for all radio-frequency superconductivity.

ATLAS can accelerate all ions up to uranium with excellent beam qualities and high intensities. It is the prime accelerator for investigating heavy-ion reactions in the neighborhood of the Coulomb barrier. To exploit its new capabilities, the experimental area at ATLAS has been enlarged, and several major new experimental systems have been installed. Among them is an eight-meter-long Fragment Mass Analyzer (FMA) that is being used to isolate very rare isotopes produced in nuclear reactions and to study their decays. Recently, an experiment at the FMA revealed the heaviest proton emitters yet observed.

Using the high-intensity uranium beams from ATLAS, Argonne is taking the lead in the study of electrons and positrons emitted in the supercritical electromagnetic fields created transiently in collisions between very heavy nuclei, such as uranium on uranium. In collaboration with seven outside institutions, Argonne has initiated a world-class program to investigate these phenomena. For the ATLAS Positron Experiment (APEX), a sophisticated new instrument capable of measuring all important parameters simultaneously has been built and installed at ATLAS.

The Laboratory is currently involved in an initiative to study the physics and technology involved in extending the heavy-ion research at ATLAS to radioactive beams. In addition to R&D on the technology, radioactive beams at ATLAS have already been used in several experiments that have provided important information on problems in nuclear astrophysics. This research is likely to expand as part of a broad-based program employing radioactive beams at a future exotic beam facility based on ATLAS.

Nuclear Theory Physics (KB-03)

Theoretical nuclear physics research at Argonne addresses a broad range of problems involving the structure and dynamics of hadrons and nuclei. There is a strong emphasis on comparing theory to data provided by experimental groups at Argonne and at research facilities around the world. Principal areas of research include nuclear dynamics with subnucleonic degrees of freedom, nuclear forces and nuclear systems, heavy-ion reactions, and nuclear structure studies.

The Laboratory's work includes modeling quantum chromodynamics in meson and baryon structure, developing reaction theories for medium-energy nucleon-nucleon interactions and meson production, and studying electron scattering within the framework of relativistic Hamiltonian particle dynamics. Recent accomplishments include (1) a successful description of threshold pion production and (2) quantum chromodynamics predictions, based on a Dyson-Schwinger equation framework, for a wide range of pion and kaon observables. Other work involves constructing realistic nucleon-nucleon potentials that give very precise and highly accurate fits to elastic scattering data and subsequent use of these potentials in detailed many-body calculations of the properties of few-body nuclei, light closed-shell nuclei, hypernuclei, nuclear matter, and neutron stars.

Theoretical heavy-ion research at Argonne addresses the structure and reactions of neutron-rich nuclei produced at radioactive beam facilities and coupled-channel calculations of reactions near the Coulomb barrier. Nuclear structure research concentrates on effective

two-body interaction studies of deformed and superdeformed nuclei observed at ATLAS. Several of these projects require major numerical simulations using state-of-the-art computers, including Argonne's massively parallel IBM SP. Many Argonne projects involve collaborators at domestic and foreign universities and at other national laboratories.

g. Materials Sciences (KC-02)

Argonne's research in materials sciences includes comprehensive studies over the entire spectrum from fundamental interactions near absolute-zero temperatures to studies of the bulk properties of solids exposed to high temperatures, radiation fields, and stresses. This research provides the scientific basis for advancing virtually all energy technologies through optimizing use of existing materials and development of new materials.

Major areas of research at the Laboratory include advanced materials, defects and radiation effects, and surface science and corrosion. The unifying theme of these studies is improving our basic understanding of materials — especially properties important for energy systems — and using this understanding to develop better materials.

Advanced Materials

Argonne is developing advanced materials by coupling experimental and theoretical methodologies to increase understanding of the basic phenomena controlling their properties. This research makes extensive use of major user facilities at the Laboratory, including the Intense Pulsed Neutron Source, where neutron-scattering investigations are conducted. This work uses neutron powder diffraction to evaluate the crystal structure of complex materials; inelastic scattering to study dynamical aspects of materials; small-angle diffraction to investigate short-range order; and polarized-neutron studies of surface, structural, and magnetic properties. The Laboratory's Basic Energy Sciences Synchrotron Radiation Center, now under construction, will facilitate application of the APS to research on advanced materials. Associated work is already underway at other facilities, such as the National Synchrotron Light Source at Brookhaven National Laboratory.

Argonne's research on superconductivity and magnetism investigates the synthesis and structure-property relationships of complex compounds having interesting superconducting or magnetic properties. At present this work is largely devoted to high-temperature ceramic superconductors (including synthesis of materials), fundamental studies related to the mechanisms of superconductivity, and development of materials more easily used in technical applications.

The Laboratory's research on layered and thin-film materials studies free surfaces, layered and superlattice systems, magnetic rare-earth and transition metals, ceramic materials, and superconducting transition metals. The Laboratory also conducts research to develop new permanent magnets by using thin-film methods.

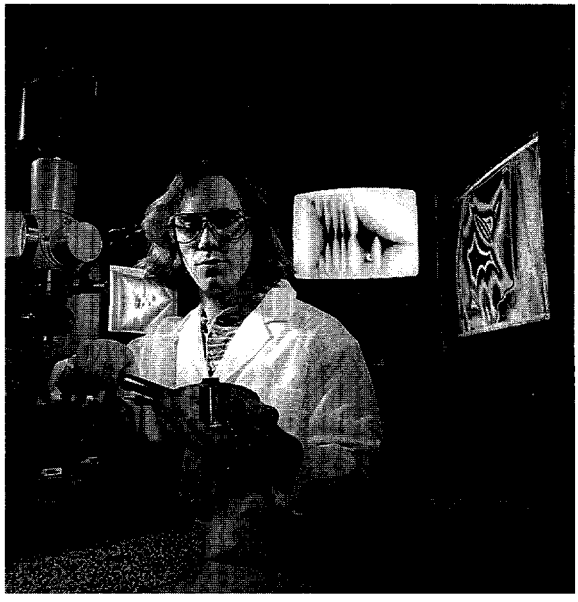


Figure V.4 The Magnetic Flux Imaging System generates images of magnetic fields in superconductors. Pinpointing the flaws in superconducting wire allows the wire's performance to be improved. Developed jointly by Argonne, Phase Metrics of San Diego, and the Institute of Solid State Physics of the Russian Academy of Sciences in Moscow, the device received an* R&D *100 Award in 1996.

Argonne's research on chemical and electronic structures focuses strongly on investigating the synthesis and properties of organic superconductors. Although superconducting transition temperatures for these materials are much lower than for ceramic superconductors, the two kinds of materials share many features, and Argonne research has notably increased transition temperatures for the organic materials.

The Laboratory's research on condensed matter theory concentrates on developing basic theoretical methods and concepts, applying these methods to complex systems by formal techniques and computer modeling, and complementing experimental research at Argonne and elsewhere. This theoretical work emphasizes superconductivity, as a complement to the Laboratory's large experimental program in that area. Strong collaboration with the Laboratory's computer science program aims particularly at using advanced computer systems to solve complex problems, such as the behavior of magnetic flux lattices in high-temperature superconductors.

Defects and Radiation Damage

Argonne's research on defects and radiation damage focuses on characterizing the structure, phase transformations, and properties of solid materials (crystalline and amorphous alloys, intermetallic compounds, and ceramics) and on investigating processes that are significantly affected by point, line, and planar defects in crystalline materials. Included in these research programs is the High Voltage Electron Microscope-Tandem Accelerator Facility, which is operated as a national user facility within the Laboratory's Electron Microscopy Center for Materials Research.

Argonne combines experimental and theoretical techniques to study the properties of interfacial structures and grain boundaries. The main goal is to elucidate problems related to ceramics processing. The theoretical work includes detailed calculations of electronic structures, investigation of dynamical phenomena via approaches such as molecular dynamics and Monte Carlo calculations, and phenomenologically based models. The experimental studies use techniques such as conventional, high-resolution, and analytical electron microscopy and secondary-ion mass spectrometry. New work aims to develop high-temperature corrosion-resistant ceramic films.

Research on irradiation and kinetic effects investigates microstructural processes and phase stability problems that occur during irradiation at elevated temperatures, to provide basic knowledge needed for fission and fusion technologies. The microstructural processes and mechanisms occurring during ion bombardment and ion implantation are studied over wide energy and temperature ranges. Primary emphasis is on understanding the influence of neutron irradiation on physical properties and on neutron irradiation effects in reactor components and fuel materials.

Surface Science and Corrosion

Argonne's research on surface science and corrosion focuses on surface and interfacial science that is relevant to energy technologies. The program develops state-of-the-art instrumentation providing extremely precise characterizations of surfaces.

Research on particle and photon interactions with surfaces has pursued theoretical and experimental investigations of fundamental issues such as sputtering mechanisms, electron-induced desorption of neutrals from polycrystalline surfaces, and strongly segregating alloy systems forming self-sustaining surface coatings. Recent work has included the development of methods for preparing high-quality diamond thin films.

The Laboratory's research on interfacial materials chemistry has focused attention on molecular sieve materials, which provide extensive opportunities for designing new catalysts by using a very wide array of experimental techniques and theoretical modeling. This work has led to the development of methanation catalysts having potential commercial value. A recent emphasis has been the development of catalysts for control of automobile emissions.

Research on aqueous corrosion is investigating fundamental phenomena at temperatures and pressures relevant to environments in fission reactors. A parallel theoretical effort is simulating solid-liquid interface phenomena. A unique aspect of this work is its integration of advanced theoretical methods with high-temperature/high-pressure electrochemical kinetic measurements and surface spectroscopies. This program also uses advanced synchrotron techniques to characterize electrode surfaces in working electrochemical cells.

Research on the chemistry of materials at high temperatures is using various theoretical and experimental techniques to determine the structural, thermodynamic, and electronic properties of ordered and associated solutions, including ionic alloys and metal/molten salt systems.

Advanced Photon Source

The APS, a new synchrotron radiation facility at Argonne, provides super-intense X-ray beams for many research areas. The APS is a national user facility for research in the materials sciences over an extraordinary range of scientific and technical questions. This new-generation X-ray source is the highest national priority among facilities for research in the materials sciences, and it promises to stimulate scientific innovation in a variety of critical technology areas.

Construction of the APS facility began in June 1990. Construction of the accelerator-housing structures and experiment hall is finished, with the linac enclosure, injection building, synchrotron tunnel, radio frequency/extraction building, and storage ring enclosure all complete. A utility building is operational and distributing utilities to the site. The completed experiment hall includes the experiment assembly area and the storage ring enclosure. The experiment assembly area is being used for modification and testing of accelerator systems. Construction of six user laboratory-office modules around the perimeter of the experiment hall has been completed. Construction of the central laboratory-office building for management, scientific, and operations staff is also complete. The state of Illinois has provided funding for a 240-bed user residence facility on the APS site. This facility is scheduled for completion in FY 1996 at a total estimated cost of $18.9 million.

The APS is in the final year of its seven-year construction schedule. In FY 1996 the Department had obligated all of the total estimated cost of $467 million. The construction project is scheduled for completion before January 1997. The APS Beamlines initiative discussed in Section IV.A.3 proposes to build additional beamlines as a line item construction project starting in FY 1999.

The goal of the APS R&D program is to conduct focused research supporting start-up of the APS accelerator components, insertion devices needed to produce high-brilliance X-ray beams, high-heat-load optics, and novel X-ray

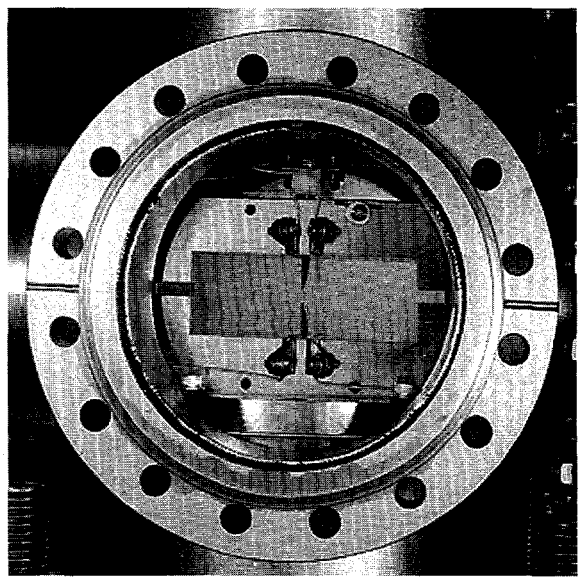


Figure V.5 X-ray beam position monitors at the APS allow the beam center to be monitored within a micrometer, or about one hundredth of the diameter of a human hair. Because intense heat load/flux from APS X-rays would quickly destroy the monitor blades used in earlier synchrotron sources, an innovative technology was required. Key to the innovation was the introduction of thin-metal-coated monitor blades made of synthetic diamond — one of the best thermal conductors and structurally toughest materials known — as shown in the center of the photograph.

detectors. The R&D related to commissioning and start-up will focus on optimizing operating conditions and on integration of accelerator systems with their diagnostics and control instrumentation.

Argonne's APS program continues to benefit from an active program of experiments at other accelerator laboratories, but the primary focus of all the program's accelerator R&D activities is now at the APS itself. A framework agreement signed in May 1993 by APS, the European Synchrotron Radiation Facility (near Grenoble, France), and the SPring-8 Super Photon Ring (under construction near Osaka, Japan) supports international collaborative research and information exchange on problems of mutual interest.

The APS project is assisting prospective users in a variety of ways. Collaborative access teams are receiving technical advice in planning and building their beamlines. In addition, policies and procedures for user safety and information exchange are being developed and implemented.

Major milestones reached in FY 1996 included first storage of an electron beam at 7 GeV and first delivery of X-ray beams to users. Dedication of the APS was held on May 1, 1996. Accelerator improvements in FY 1996 will further increase system performance. Installation of beamline front ends and insertion devices for approved collaborative access teams is planned for FY 1996 and FY 1997.

The requirements of users and the facility's capabilities are becoming better defined as users plan their research programs. The radiation characteristics desired by users and the specialized insertion devices required to satisfy this need at the APS will continue to be a primary focus of research. A continuing concern will be to increase capabilities to handle the high power of APS X-ray beams without losing their brightness or polarization properties. The R&D on new materials and material fabrication techniques will continue to aim at better ways of confining, defining, and controlling the powerful radiation from the insertion devices. An important objective is standardizing user beamline components and the beamline control software. The need for detectors with unique timing capabilities will continue to be addressed.

Intense Pulsed Neutron Source

Argonne's IPNS is the nation's most cost-effective neutron source for research on condensed matter. It is officially designated a national user facility, serving the needs of universities, industry, and other government laboratories. Investigations range broadly and include determinations of the structure of high-critical-temperature superconductors, magnetic field profiles at the surfaces or interfaces of materials, diffusion at polymer interfaces, the potential of hydrogen in metal hydrides, and structure and dynamics in amorphous solids and liquids. Other studies focus on the role of template molecules in the crystallization of zeolites, momentum states in quantum fluids, residual stress states in steels and composite materials, high-energy excitations in mixed-valent and itinerant magnets, and second-phase

Figure V.6 At the IPNS, Argonne researchers adjust the polarized neutron beam by using the super mirror analyzer on the POSY reflectometer. POSY is used to study near-surface behavior such as magnetic multilayers and also bonding and diffusion in polymers.

formation in metal alloys. Long-wavelength neutrons from cold liquid and solid methane moderators, in conjunction with the unique time structure of the pulsed neutron source, have allowed development of a number of valuable techniques such as (1) the reflection of neutron beams to investigate magnetic surface phenomena and polymer diffusion and (2) quasielastic scattering to observe molecular rotation and motion.

In FY 1996, IPNS operated for 25 weeks under DOE sponsorship and for 2 weeks as part of the National Science Foundation's Science and Technology Center for High Temperature Superconductivity.

h. Chemical Sciences (KC-03)

Argonne's research in chemical sciences encompasses a broad spectrum of fundamental investigations into atomic, molecular, and macroscopic phenomena. These investigations provide the scientific foundations needed to develop new energy technologies. Argonne's program in chemical reactivity now involves 11 major research areas: (1) reactive intermediates in condensed phases, (2) electron transfer processes in chemical systems, (3) photochemical energy sciences, (4) chemical dynamics in the gas phase, (5) photoionization-photoelectron spectroscopy, (6) metal cluster chemistry, (7) coal chemistry, (8) fluid catalysis, (9) the separation science of the heavy elements, (10) the chemistry of the heavy elements, and (11) lithium batteries.

Argonne's research on reactive intermediates in condensed phases focuses on the chemistry of short-lived intermediates of radiolysis (such as radicals, radical ions, and the excited states of molecules) and the roles of solvents and matrices in modulating their reactivity. Separate research addresses solid-state chemistry and high-energy chemistry. The former work aims to unravel the influence of the structural order of solid matrices on chemical processes such as proton transfer, on the reactivity of transient intermediate species, and on energy disposal modes after irradiation. The high-energy research explores the dynamical behavior of highly excited species and excited radical ions generated by ultrashort (picosecond and subpicosecond) pulses of electrons and energetic photons. To develop the capability for studies in the subpicosecond time domain, Argonne proposes to construct a laser-driven linac (see below).

Argonne's research on electron transfer will continue to focus on investigating the basic principles that govern the rates of electron transfer processes. Investigations in this area are exploring new theoretical directions and advanced approaches, such as combining linac and laser excitation to study in such systems the photochemistry of radicals and radical ions and of photoinduced electron transfer reactions. Successes in experimental exploration of the dependence of electron transfer rates upon distance, energy, molecular structure, and temperature are providing a foundation for definitive tests of theoretical models and for complementary development of theory and experiments.

Argonne's research in photochemical energy sciences seeks to understand the mechanisms of electron transfer and charge separation in molecular systems that mimic photosynthetic energy conversion mechanisms and to use this knowledge to guide the design of molecular photoconversion systems. These systems are studied by using a variety of spectroscopic techniques (such as time domain electron paramagnetic resonance; neutron, X-ray, and anomalous X-ray scattering techniques; and ultrafast optical spectroscopy), synthesis, and theory. In addition, the Laboratory uses its capabilities in synthesis to produce new tailored structures that help to resolve key issues in achieving rapid and controlled electron and charge transfer in synthesized systems.

Argonne's research on chemical dynamics combines theoretical work on the energetics and dynamics of chemical reactions with experimental work on chemical dynamics and kinetics. This broad effort is especially important to combustion science, and it will also contribute to a general understanding of the fundamentals of chemical reactivity. Theoretical investigations of the reactivity of large molecules, such as aromatic radicals, will

continue, as will important new theoretical and computational work to develop quantum chemistry codes for advanced parallel processors. Argonne is playing a leading role in the exploitation of this opportunity through collaborative programs such as Argonne's Center for Collaborative Science and Technology initiative. The Laboratory is investigating radical reactions through experimental studies of state-selective chemistry in a flow reactor. Work on the chemical kinetics of combustion reactions has moved to the study of atom-radical reactions. Related photoionization-photoelectron experimentation aims to establish the thermodynamic properties of reactive intermediates important in combustion. Plans call for these two areas of research to be more strongly coupled. This wide-ranging experimentation provides a strong foundation for testing new theoretical models of chemical reactivity.

Argonne's research on metal cluster chemistry considers the chemical reactivity, product composition, kinetics, chemisorption reactions, catalytic properties, and structures of metal clusters ranging in size from 4 to 200 atoms. In closely linked experimental and theoretical studies, this program is developing a relationship between cluster structure and reactivity. Plans call for studies of metal cluster oxides, bimetallic clusters, and alloy clusters; investigation of the catalytic properties of size-selected transition metal clusters collected on appropriate substrate materials; initiation of a program to conduct X-ray spectroscopic studies at the APS; and continuing theoretical dynamics studies. One particular future thrust will involve the study of unimolecular reactions on cluster surfaces. Another will expand theoretical work aimed at formulating correlations between the structural, magnetic, and optical properties of clusters. With theoretical efforts addressing reactive intermediates in condensed phases, electron transfer processes in chemical systems, and photosynthesis and solar energy conversion and with theoretical effort in the area of metal cluster chemistry, most of the Laboratory's research on chemical reactivity strongly links theory and experimentation.

In the area of chemical energy, Argonne's research on the characterization and reactivity of coals and coal macerals has focused on identifying the most important organic structures in coals and separated coal macerals and on the relationship of these structures to the chemical and thermal reactivity of the materials. Future research will address a wide range of vital issues in coal chemistry, including ecosynthesis of coals and macerals, the origin of long-chain alkyl aromatic compounds, pathways for hydrogen atom transfer, the structural chemistry underlying the problem of cross linkage, development of multidimensional nuclear magnetic resonance imaging techniques, the synthesis of large-pore catalysts for converting heavy liquids derived from coal and related materials to fuel, and evaluation of the potential of synchrotron X-ray absorption spectroscopy for studies of the structure of coal and catalysts.

Argonne's Premium Coal Sample Facility has reached its primary goal. Eight different coals have been processed, and more than 23,000 samples have been distributed to coal scientists.

The central objective of Argonne's research in fluid catalysis is to explore new catalytic chemistry for transforming simple precursor molecules (such as carbon monoxide, methane, methanol, nitrogen, and hydrogen, which are frequently used in industrial processes) to desired products. This research employs supercritical fluids and novel strategies based on magnetic resonance to study catalytic reaction chemistry *in situ* at high pressure and temperature. New research will exploit supercritical media for studying basic processes in catalysis, explore the potential of metallomacrocycles in aliphatic hydrocarbon activation chemistry in the solution phase, and investigate ceramic precursor transformations that are associated with the synthesis of advanced materials.

Argonne's work in separations science aims to develop and characterize new separation processes applicable to environmental restoration and waste management. A central focus is the design, preparation, and evaluation of new extractants. Research will continue on the design and synthesis of new extractants in which the solvating molecule is built into the structure of the extractant so that intramolecular extraction can occur. Another focus will be the

development of multifunctional phosphonate extractants. In addition, the Laboratory plans to synthesize extended molecular structures in which molecular recognition occurs in two distinct stages.

Argonne's research in heavy-elements chemistry has been linked with work in separations science to expand investigations in areas likely to bear on important issues relating to environmental restoration and waste management. In its work on heavy-element coordination chemistry, the Laboratory emphasizes design of new ligands, spectroscopy studies of the f-elements in various coordination environments, and investigations probing the influence of f-elements on the cooperative properties of materials containing them. Also being sought are new options for waste disposal and site cleanup and for actinide monitoring and safeguards. Research will continue to develop structure-property relationships for actinide ions in crystalline and amorphous phases, such as glass containing nuclear waste. Other new work will investigate the structure and actinide-encrypting behavior of heteropolyanion clusters.

Argonne has begun fundamental studies to elucidate and resolve key issues that limit the performance of rechargeable lithium batteries used in nonautomotive applications. One goal for lithium secondary batteries is preparation of carbon electrodes that exhibit superior performance as the negative electrode. The promising approach to be employed here is synthesis by design exploiting template synthesis techniques. Argonne is also exploring the utility of *in situ* nuclear magnetic resonance spectroscopic imaging for studying electrode-electrolyte interfaces and solid-state ion transport mechanisms in lithium-polymer electrolyte batteries. Further issues to be studied are the factors that influence film growth at electrolyte-electrode interfaces, the fundamentals of dendrite formation on lithium anodes, and the transport numbers of lithium ions. A new research program is coupling experimental and theoretical approaches, including neutron and X-ray scattering and *ab initio* molecular orbital theory, to elucidate the structure, dynamics, and ion transport properties of lithium-polymer electrolytes.

Initiative: Fundamental Chemistry of Radioactive Waste

Argonne proposes a new research program responding to a national need for fundamental chemical knowledge of reactions occurring in radioactive waste. This need was recently highlighted by "hydrogen burping" problems in waste tanks at one of DOE's major waste-handling laboratories. Discussions with technology experts from several laboratories with similar activities confirm the need for improved information about the fundamental chemistry involved.

Argonne will pursue three lines of investigation. The first will probe, via fundamental studies, the stability of solid radioactive waste forms. The second will investigate primary radiation chemical processes in concentrated solutions typical of radioactive waste. The third will elucidate NO_x chemistry in similar solutions. The intent is to identify intermediates, products, and reaction mechanisms, allowing development of more meaningful predictive models.

Funding is sought from the Chemical Sciences Program (KC-03). Required resources are summarized in Table V.5.

Table V.5 Fundamental Chemistry of Radioactive Waste ($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	1.0	2.5	2.7	2.7	2.7	2.5	2.5
Capital Equipment	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-
Total	1.0	2.5	2.7	2.7	2.7	2.5	2.5
Direct Personnel	5.5	14.7	14.8	14.8	14.8	14.0	14.0

Initiative: Linear Accelerator Upgrade — Ultrafast-Pulse Radiolysis Facility

Argonne proposes to upgrade its present linac to a new pulse radiolysis facility that will enable the study of the very fast chemical phenomena that are important for understanding (1) the radiolytic processes occurring in

radioactive waste and (2) other fundamental issues in chemical reactivity, such as the chemistry of reactive intermediates, charge and electron transfer and transport, and ion solvation. (See the related initiative, Fundamental Chemistry of Radioactive Waste, and the discussion above of Argonne's work on reactive intermediates and electron transfer.) This new laser-driven electron accelerator device will revolutionize generation and detection capabilities in pulse radiolysis experiments.

Many basic research studies needed to investigate these fundamental issues are not possible with any existing accelerator, because the required time resolution is not attainable, and detection capabilities are limited. The new facility will supply the needed shorter pulses with synchronized laser beams for pump-probe measurements. It will also provide a much higher current in 50-ps pulses, which will facilitate many studies of fast phenomena that are not presently possible. Even the study of rapid charge transfer reactions in liquids and gases should become possible.

The new pulse radiolysis facility will include a linear accelerator based on novel technology for the injector and acceleration sections and will reuse much of the existing linac transport system in a simplified configuration. The facility will have a laser-driven photocathode, with a portion of the laser light available to provide precisely synchronized probe light for optical detection. Design goals are electron pulses with energy greater than 10 MeV and a charge per pulse of 3 nC for a pulse that is less than 1 ps wide and 50 nC for a pulse that is 50 ps wide. Differences in pulse length are attainable because of the ability to keep the charge together in space (space charge limitation). Construction will comprise (1) computer simulations to determine machine configurations for the generation of the larger pulses (> 50 nC) and ultrashort pulses (< 1 ps); (2) reconfiguration of the present experimental hall for simpler operation and maintenance and removal of old components; and (3) design, construction, and assembly of a laser-driven photocathode, accelerating cavities, an excitation laser, supports, control systems, and focusing systems. The accelerator will employ the L-band linac radio-frequency system and the klystrons from the present linac. Advantage will also be taken of the experience of Argonne's high energy physics group in building high-current, short-pulse accelerators using laser-driven photocathodes.

Funding is sought from the Chemical Sciences Program (KC-03). Required resources are described in Table V.6.

Table V.6 Linear Accelerator Upgrade — Ultrafast-Pulse Radiolysis Facility
($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	-	-	-	-	-	-	-
Capital Equipment	-	-	-	-	-	-	-
Construction	-	-	1.5	0.9	0.3	-	-
Total	-	-	1.5	0.9	0.3	-	-
Direct Personnel	-	-	1.0	1.0	1.0	-	-

i. Atomic and Molecular Physics (KC-03)

Argonne's work in atomic and molecular physics focuses on precise structural measurements of atomic ions and small molecules and measurements of the dynamics of collisions of atoms with fast-moving ions. Argonne's unique set of accelerator facilities allows promising new research in these areas. These facilities include the upgraded ATLAS facility with an electron cyclotron resonance (ECR) source injector on a high-voltage platform, which provides energetic beams of highly stripped atoms, up to uranium in weight, and the ion beam-laser interaction facility, Blase. Most importantly, Argonne's APS, which is to be commissioned by the end of 1996, will allow new atomic and molecular studies with high-intensity, high-energy X-rays. At existing synchrotron facilities, Laboratory researchers are currently measuring photoionization and scattering processes in atoms and ions.

Research in atomic physics at ATLAS encompasses studies of atomic structure and atomic collisions. Use of photon coincidence techniques provides precise lifetime measurements in few-electron ions to test both quantum

electrodynamic and other relativistic correlation effects. Beam-foil spectroscopy is used to measure structure in many-electron, highly charged ions. Studies of atomic collisions improve understanding of interaction mechanisms and dynamics. Detailed knowledge of ion-atom collisions provides important input for plasma physics, astrophysics, laser technology, and other fields.

Initiative: Atomic Physics at Synchrotron Light Sources

Argonne is developing a new research program in synchrotron-based atomic physics that will take advantage of the unique capabilities of the Laboratory's APS. This program uses hard X-ray synchrotron radiation to study photo effects of atoms and ions and to advance understanding of multielectron correlation effects and relativistic effects in the structure and dynamics of inner-shell electrons of heavy atoms and ions. Combining laser-excited targets with synchrotron radiation enables the study of high-field effects at short wavelengths. Resource requirements are described in Table V.7. Funding is sought from the Chemical Sciences Program (KC-03). Funding for equipment was received in FY 1993 through FY 1996.

Table V.7 Atomic Physics at Synchrotron Light Sources ($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Capital Equipment	0.3	0.5	0.5	0.2	0.2	0.2	0.2
Construction	-	-	-	-	-	-	-
Total	1.3	1.5	1.5	1.2	1.2	1.2	1.2
Direct Personnel	5.0	5.0	5.0	5.0	5.0	5.0	5.0

j. Engineering and Geosciences (KC-04)

Argonne is applying synchrotron radiation techniques to fundamental problems in the geosciences. Specific techniques being used include static and time-resolved X-ray scattering, X-ray spectroscopy, and X-ray standing-wave studies of geologic materials under controlled conditions. The objective is to gain new insights into the atomic-scale processes occurring at mineral-water interfaces, in aqueous electrolyte solutions, and in minerals and rocks under a wide range of physical conditions. Success will allow better prediction of complex macroscopic geologic transport phenomena, particularly those occurring in natural rock-water systems. These phenomena are crucially important for a wide range of energy technologies.

k. Advanced Energy Projects (KC-05)

For the Advanced Energy Projects Program, Argonne is working on three projects.

The first project is exploiting recent developments in the field of carbon chemistry and in the technology of broad-beam ion sources to develop a method of direct carbon film deposition that (1) circumvents the need for high substrate temperatures, (2) results in high deposition rates, (3) is capable of covering large areas uniformly, and (4) reduces or eliminates the need for the presence of hydrogen during deposition. Achievement of this last goal will enable growth of diamond films with high crystalline perfection and very low impurity content, opening a wide range of possible industrial applications.

The second project will develop a new class of materials for use in producing energy-efficient image-processing microdevices. These materials will exploit the photorefractive effect, a light-induced change in the refractive index of a nonlinear optical material that results from photogeneration of a space charge field caused by directional charge transport over macroscopic distances within a solid. The only high-quality photorefractive materials commercially available today are expensive single crystals of inorganic materials such as barium titanate. Argonne is proposing a new approach that combines cheap, easily processed organic materials with a built-in method to obtain the solid-state order necessary to achieve photorefractivity comparable to that seen in inorganic crystals. This approach uses organic molecules that undergo a transition to a liquid

crystalline phase above ambient temperatures. Self-ordering in the liquid crystalline phase, followed by cooling to an ordered molecular solid, will impart both good optical nonlinearity and directional photoconductivity to thin solid films of these materials. These solid films have the potential for greater photorefractive sensitivity and faster response times than any material developed to date.

The third project will develop knowledge about the chemistry of iron and sulfur in subsurface reservoirs that can be exploited to improve U.S. oil production from souring reservoirs. This project involves (1) studies of origins and interrelationships for microbiologically mediated and chemically produced sulfides under various relevant conditions, (2) characterization of iron-sulfur species by use of a suite of spectroscopic and analytical techniques, and (3) development of Mössbauer spectroscopy for field measurement and identification of iron-bearing solids obtained from drillings. The resulting comprehensive knowledge of the exact chemical and physical states of iron in production zones and waters can guide chemical treatment programs and increase oil production.

In the future, Argonne plans to develop novel photocatalysts that will sequester heavy metal ions and convert them to their readily recoverable metallic forms. The catalysts will be designed by modifying the surface of colloidal TiO_2 by using various chelating agents to enhance the redox properties of TiO_2 and the adsorption of heavy metal ions. Also to be investigated is development of photocatalysts for simultaneous recovery of heavy metals and destruction of organics. This work promises to be the basis for a new technology for removing heavy metals from contaminated groundwaters and aqueous waste streams encountered at DOE and industrial operations.

In a project designed to take advantage of the extraordinary selectivity afforded by molecular recognition processes and the cost-effectiveness of precipitation processes, Argonne proposes to develop a new type of chemical separation method called two-stage molecular recognition. Emphasis will be on the selective isolation of hazardous metals and nonmetals from dilute solutions. This new method will involve the binding of target metal ions by a selective chelating agent, after which a second agent will agglomerate the bound metal complexes and precipitate them from solution. Such methods promise to be valuable for treating large wastewater volumes, because the target metal ions are removed by precipitation.

A new study will explore the advantages of advanced oxidation technology for the destruction of chelating agents and the recovery of metals. This methodology, which will involve the photolysis of hydrogen peroxide solutions, will have the potential to reduce significantly the volume of waste encountered in many hazardous and nuclear process streams and in contaminated sites.

I. Mathematics and Computer Science (KC-07)

The overall goal of Argonne's program in mathematics and computer science is to advance the state of the art of large-scale scientific computing. Recognizing the importance of strong interactions between mathematics, computer science, and computational science, researchers focus on advanced methods for solving scientific and engineering problems.

Argonne's research addresses both numerical and nonnumerical computing. Numerical studies focus on designing parallel algorithms for unstructured mesh computations, exploiting interior point methods for solving optimization problems, providing a new methodology for computing derivatives, and devising software tools for high-performance computer systems. Nonnumerical efforts center on designing and using a powerful automated reasoning program to obtain proofs of mathematical theorems.

A vital part of this work is collaboration with computational scientists at Argonne to ensure that computing science results are transferred to scientific applications. For example, a project related to materials science is investigating vortex dynamics in high-temperature superconductors. Other work related to biological and medical research

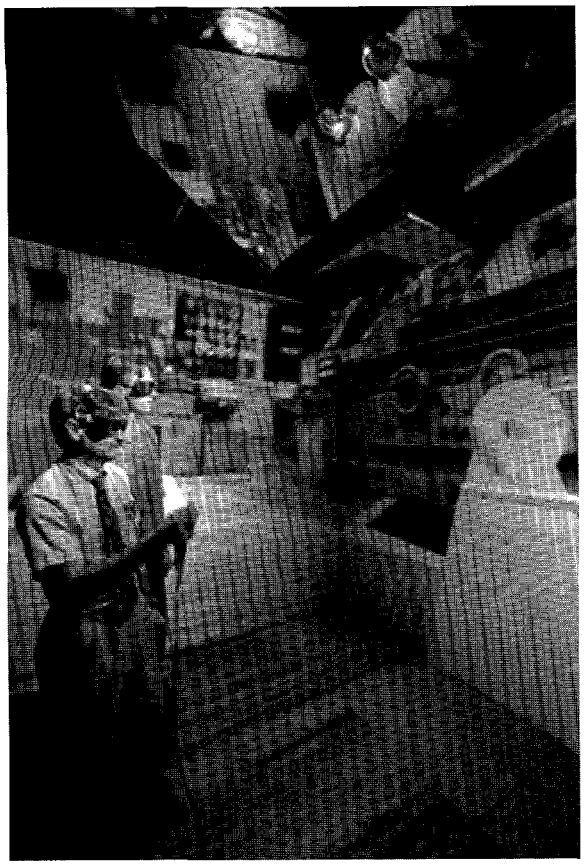


Figure V.7 Argonne's CAVE Automatic Virtual Environment, linked to the Laboratory's massively parallel IBM SP supercomputer, is used to help computational scientists understand dynamic processes and multidimensional configurations.

focuses on protein-protein interactions and enzyme properties. In addition, a project in computational chemistry promises to lead to commercial applications involving environmental protection and restoration, combustion, and chemical processing.

Essential to all this work is Argonne's High-Performance Computing Research Facility, which features a massively parallel 128-node IBM SP computer. Via networks, this facility is also available to outside collaborators. (See Chapter XI for additional information.)

Argonne continues to participate as a partner in the National Science Foundation's Center for Research on Parallel Computation. The Center brings together scientists from Argonne, the California Institute of Technology, Los Alamos National Laboratory, Rice University, Syracuse University, the University of Tennessee, and the University of Texas to harness the power of advanced computers for solving scientific problems. Center funding supports research in parallel computing and maintenance of advanced computers at Argonne.

Using advanced computers and the experience gained from exploratory research, Argonne plans to continue demonstrating the performance of parallel processing and visualization for applications of seminal importance to science and technology.

m. Energy Research Analyses (KD)

Argonne is supporting DOE and the National Acid Precipitation Assessment Program (NAPAP) through development and operation of the Tracking and Analysis Framework, an assessment tool for policy analysis that integrates credible scientific models. The tool will be used by NAPAP in developing its 1996 assessment report to Congress.

n. University/Laboratory Cooperative Program (KT)

The DOE University and Science Education Programs provide extensive opportunities for faculty and students from all educational levels to participate in Argonne's research programs and use its research facilities. These very important opportunities and associated educational programs are described in Section VI.B.

Argonne hosts the largest educational program among the DOE national laboratories.

o. Laboratory Technology Research Program (KU)

The Energy Research-Laboratory Technology Research (ER-LTR) Program provides a bridge from basic to applied research. With ER-LTR funding, Argonne further develops

technologies that, with additional technical work complementing the Laboratory's existing research programs, could result in near-term products or processes with commercial applications.

By January 1996 the ER-LTR Program had funded 72 of the Laboratory's 115 new cooperative research and development agreements (CRADAs), 24 personnel exchanges, and 60 technical services program agreements. (See Section VI.A.1 and also discussions throughout this chapter that note ER-LTR activities in the context of related DOE programmatic work.) In addition, the ER-LTR Program helps to fund major industrial initiatives such as AMTEX (the American Textiles Partnership) and the Advanced Computational Technology Initiative, which involve multiple laboratories and many industrial firms in work toward broad technological advancement of entire industries.

Many of the CRADAs funded through the ER-LTR Program have been co-funded with other DOE offices, including Energy Efficiency and Renewable Energy, Fossil Energy, and Environmental Management. The resulting melding of basic and applied research perspectives encourages developments with practical applications.

The ER-LTR Program also supports technology maturation projects at Argonne, which have the unique objective of supporting key areas of technology research to a point where applied DOE programs or industry take over development. Block funding of technology maturation research and cost-shared research with industry is particularly valuable, because it immediately allows a DOE laboratory to pursue novel directions that complement current programmatic objectives.

From FY 1995 to FY 1996, Argonne's ER-LTR funding dropped from $10.5 million to $2.5 million. The Laboratory reallocated programmatic funding to continue all but one ongoing ER-LTR research project with an industrial R&D partner. However, no new projects will be initiated in FY 1996 except for the small-scale Technical Services Program agreements. (See Section VI.A.1.e.) Unless funding is restored in the future, Argonne's valuable partnership activities will be largely restricted to those that can be supported from direct program budgets.

3. Energy Efficiency and Renewable Energy

Argonne conducts important work for the Assistant Secretary for Energy Efficiency and Renewable Energy in support of programs including Electric Energy Systems, Industrial, and Transportation. Also important is Argonne's technology center for the commercialization of superconductivity, which is discussed further in Section VI.A.

a. Electric Field Effects (AK-04)

Argonne is investigating appropriate limits on electric and magnetic field strengths for human populations near high-tension electric transmission lines and switch gear. The Laboratory is specifically investigating the question of how and why 60-hertz electric and magnetic fields cause chronobiological effects in small mammals.

b. Systems Technology (AK-06)

A major Argonne experimental research program is improving the properties of high-temperature superconductors and developing fabrication methods suitable for their commercial production. Teaming relationships with industrial partners arranged through the Laboratory's High Temperature Superconductivity Technology Center are a key aspect of this work.

Argonne's applied research to develop better high-temperature superconductors and technologies to use them is strongly linked to the Laboratory's basic research on superconductivity. The Laboratory is working with several wire-making companies to increase the critical current density in long lengths of wire. Following up earlier successful inventions, the Laboratory is also pursuing several near-term

applications, including a cryogenic "dipstick" sensor of liquid levels (marketed by Illinois Superconductor), high-temperature-superconducting down-leads for electrical connections to devices cooled with liquid helium (being developed with several individual companies), and a low-loss magnetically levitated bearing with a wide variety of potential applications (being developed in cooperation with Commonwealth Edison Co.). Under contracts with Tokyo Electric Power, the Laboratory has developed a 1,000-ampere conductor for electric power transmission and leads for a fault-current interrupter.

The High Temperature Superconductivity Technology Center is managed and staffed by Argonne scientists, with technical support partly provided by students from colleges and universities across the nation. By combining state-of-the-art facilities with highly qualified technical support, the Center is attracting industrial participation. The Center will provide a focal point for interactions between Argonne scientists and engineers involved in industrial process design and product development. In FY 1995, researchers from American Superconductor Co., Intermagnetics General Corp., Illinois Superconductor, Commonwealth Research Corp., and Superconductive Components, Inc., are participating. The associated college training programs are an important source of skilled employees to U.S. industry.

For the DOE Office of Utility Technology, Argonne is assessing potential applications of high-temperature superconductors. Work on implications for the electric power industry is being supported by that office and by organizations in foreign countries, including Canada, Denmark, Finland, Germany, Israel, Italy, Japan, the Netherlands, Norway, Sweden, Switzerland, Turkey, and the United Kingdom. Recently, Austria and Russia expressed interest in participating.

c. Building Technologies (EC)

In cooperation with Bethel New Life, Commonwealth Edison, the Chicago Housing Authority, and the Habitat Company, Argonne is conducting field tests of energy conservation measures for both substantial and moderate rehabilitation of housing in inner-city Chicago neighborhoods. The Laboratory is also providing technical assistance for energy-conserving modifications to commercial buildings as part of DOE's Rebuild America Program.

Initiative: Urban Technology

The Urban Technology initiative represents a consolidation and focusing of a number of Argonne capabilities to foster the application of technologies in the areas of energy efficiency, environmental characterization and remediation, pollution control, and information systems, in order to achieve cost-effective redevelopment of urban areas. In short, the initiative will place appropriate advanced methods and technology in the hands of businesses, not-for-profit organizations, and local governments to achieve urban redevelopment.

The DOE Buildings Efficiency Research Program has provided initial funding for Argonne activities in such areas as energy audits, computer simulation of energy use in buildings, instrumentation of buildings to monitor energy use, home energy rating, energy bill analysis, engineering cost analysis for energy conservation measures, and development of new construction technologies. Argonne has used the results in work with community development groups such as Bethel New Life, the Kenwood-Oakland Community Organization, People for Community Recovery, and the West Cluster Coordinating Committee for Chicago's Empowerment Zone. Technical assistance for community housing developers will be especially important to DOE as it pursues its five-year goal of incorporating aggressive energy conservation measures in one million existing housing units throughout the nation.

In earlier DOE work, Argonne developed a substantial capacity for addressing site characterization and remediation issues associated with brownfield redevelopment. Relevant technologies include an expedited site characterization methodology (which has already been transferred to minority- and women-owned firms), accelerated decision-making models

Figure V.8 Bethel New Life, a community development corporation on Chicago's West Side, contracted with a small minority-owned business to characterize potential environmental hazards on a large vacant lot. Argonne staff provided training and technical advice, transferring unique site-characterization expertise to the small business. Similar approaches could be used for sites in other cities.

and tools (developed with private-sector firms through CRADAs), databases that evaluate characterization and remediation technologies (developed under the DOE Technology Connection Program, led by Argonne and supported by Pacific Northwest National Laboratory), bioremediation technologies, and development of guidance approaches for future land use. Under the Urban Technology initiative, these skills and tools will be targeted to make brownfield sites a viable alternative to greenfield development, with advantages for both urban finances and job creation.

Argonne's major capabilities in information technology will benefit this initiative in two main ways. First, new information retrieval technologies developed by Argonne for DOE (the Facility Profile Information Management System, for example) can be used by local governments for better consolidation, retrieval, and evaluation of data concerning land use, which is currently a serious deficiency in many redevelopment programs. Second, new spatial analysis techniques using geographic information systems and visualization technologies, such as the Dynamic Environmental Effects Model, can serve as planning tools for urban redevelopment.

Argonne technologies in pollution prevention and waste minimization have already been put to work at urban industrial sites. Technologies such as recycling auto fluff and dezincing scrap steel are promising bases for urban factories on brownfield sites.

Limited funding has been received from the Office of Building Technology, Office of Energy Efficiency and Renewable Energy (EE), and additional funds will be sought from this and other sources. Required resources are described in Table V.8. Possible NEPA-related impacts and costs will be considered as individual elements of the initiative are planned and implemented.

Table V.8 Urban Technology
($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	0.2	1.0	3.0	3.0	3.0	3.0	3.0
Capital Equipment	-	-	-	-	-	-	-
Construction	-	-	-	-	-	-	-
Total	0.2	1.0	3.0	3.0	3.0	3.0	3.0
Direct Personnel	1.5	5.0	11.0	11.0	11.0	11.0	11.0

d. District Heating and Cooling (EK-61)

In collaboration with industrial firms and universities, Argonne is developing advanced technologies and components that will make district heating and cooling more efficient and a greater contributor to energy efficiency. Pioneering research with advanced energy transmission fluids has demonstrated that pumpable ice-water slurry can be used in place of chilled water to deliver cooling. As an energy transport fluid, ice slurry has high energy density, so it improves the thermal-hydraulic performance of chilled-water cooling systems, reduces system capital costs, and improves utility load management systems, thereby saving energy and cost. The Laboratory has collaborated with Northern States Power and the Electric Power Research Institute to design and install a small field test of this new concept using ice slurry for district cooling. Related work is addressing the fundamentals of heat transfer and pressure drop

in ice slurry flows. The Laboratory is currently exploring the possibility of conducting a large-scale ice slurry demonstration in collaboration with a local utility and equipment manufacturers.

e. Industrial (ED)

Argonne's work for DOE's Industrial program includes support for Industry Visions of the Future, which addresses the major energy users and waste producers, including the petroleum refining, chemicals, forest products, steel, aluminum, metal casting, and glass industries.

In collaboration with U.S. industry, Argonne has begun to develop a number of innovative technologies that will reduce the approximately 12 billion tons of waste produced by U.S. industries each year. This work also emphasizes reducing industrial energy consumption attributable to the inefficiencies associated with waste materials. The initial focus is on the chemical industry, which is the nation's largest generator of wastes and also one of its largest consumers of energy.

Argonne's continuing research on ways to increase utilization of scrap metals is currently focusing on base metals and the residuals that result from their commercial recovery and processing from scrap (e.g., salt cake and automobile shredder residue). The objective is to develop, in collaboration with industry, new technologies to economically recycle components and materials from cars and other consumer durables (such as appliances, carpeting, and roofing), while maximizing net energy benefits. The research scope includes recycling of obsolete goods and residues from manufacturing and secondary processing; it also addresses the redesign of goods to facilitate later recycling. This work emphasizes involvement with individual companies and with trade associations such as the Institute of Scrap Recycling Industries, the American Iron and Steel Institute, the Aluminum Recycling Association, the American Foundryman's Society, the Brass and Bronze Ingot Manufacturers, the American Plastics Council, and the Vehicle Recycling Partnership among Ford, General Motors, and Chrysler.

Argonne and Metal Recovery Industries, Inc., developed a new process to separate and recover steel and zinc from scrap galvanized steel. The process currently is being demonstrated at pilot scale; establishment of the first commercial demonstration plant is being negotiated.

Argonne is developing a process to recover plastics from shredded obsolete automobiles and white goods after the metals have been removed. The process uses physical separation followed by chemical leaching, and it significantly decreases the volume and cost of the waste disposal that is ultimately necessary. Cost-sharing arrangements for a scaled-up commercial demonstration are currently being negotiated. Pilot-scale testing of the recovery operation used for polyurethane foam has begun, and a 20,000-pound evaluation batch is being prepared.

Argonne is evaluating physical and chemical separation techniques for recovering the metallic and flux contents of salt cake from secondary aluminum smelters. If it is not recycled, the waste salt cake must be deposited in landfills at substantial cost. The Laboratory is also examining opportunities for producing high-volume aluminum-based chemicals and specialty products from the recovered aluminum oxides.

Argonne has developed a process for producing competitively priced lactic acid from waste carbohydrates such as food processing waste and has used lactic acid to produce plastic and other chemical products that are nontoxic and biodegradable. Argonne's technology can produce higher value products while reducing waste disposal problems and replacing petroleum feedstocks. The process uses a microbial consortium of *Lactobacillus* strains and simultaneous fermentation to produce the lactic acid. The Laboratory has developed a new technique involving electrodialysis desalting and water-splitting membranes to purify the lactic acid economically and avoid the production of a troublesome gypsum by-product. Attention now centers on additional

processing steps required to purify the lactic acid for use in new nontoxic, biodegradable products such as solvents, biodegradable plastics, and plasticizers. Licenses for restricted fields of use have been granted, and private companies are working with Argonne to test the technology.

Argonne assists DOE's Office of Industrial Technologies by performing R&D and by promoting technology transfer and commercialization of improved cogeneration and related technologies in the industrial sector. The Laboratory conducts analytical, technical, and economic studies and performs R&D on advanced cogeneration systems, components, and related technologies.

Under a cost-shared program with industry, Argonne developed state-of-the-art computer software that simulates the metal casting process. As an outgrowth of this work, Argonne has begun to develop software to simulate the welding process. Resulting processes could produce superior castings and welds at significantly lower capital and operating costs.

Argonne is providing economic analysis support to DOE, including analysis of (1) energy-intensive industries (based on confidential plant-level census data) and (2) the economic benefits of programs addressing energy efficiency, advanced motor vehicles, and renewable energy.

Argonne is cooperating with the National Renewable Energy Laboratory (NREL), Idaho National Engineering Laboratory (INEL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL) on R&D aimed at converting biomass materials to useful chemicals. The initial objective is the economic production of succinic acid and downstream products. Argonne is addressing metabolic engineering to improve the tolerance to succinic acid of the microorganisms involved, separations and purification, and product development. ORNL is examining novel reactor designs, which may lead to new methods for removing product streams; NREL is conducting economic analysis, program management, and research on biomass processing; INEL is examining the life cycle costs of potential products; and PNNL is mainly developing new products.

Argonne is helping DOE's Office of Industrial Technologies identify and evaluate the R&D needs of the petroleum refinery industry. The objective is to ensure that the petroleum industry will be able to respond to market forces that affect the operations and economics of refineries while it meets demands for enhanced energy efficiency, effluent management, and waste minimization.

Argonne is developing technology for advanced fluidized catalytic cracking in the refinery industry, which is expected to (1) tailor product yields more closely to meet mandated gasoline reformulations, (2) reduce emissions, (3) increase thermal efficiency, (4) produce more transportation fuel per barrel processed, and (5) improve cost competitiveness. The Laboratory is working on validated design tools and associated databases that will be available to all industrial organizations interested in pursuing individual commercial opportunities.

Argonne's interdisciplinary thermal sciences program merges the fields of chemical and mechanical engineering, applied thermodynamics, heat and mass transfer, fluid mechanics, and chemical kinetics, to address problems facing the chemical processing and petroleum refining industries. The program focuses on developing and applying a comprehensive understanding of the mechanisms governing the thermal performance of systems, subsystems, and components in the process industries. Specific research areas include the control and mitigation of fouling; enhancement of heat transfer in heat exchangers, condensers, and evaporators; plate-frame and plate-fin heat exchangers; multiphase, multicomponent heat and mass transfer; separation technologies; and energy management and integration.

Understanding the mechanisms that control surface fouling is important for several major industries. Equipment that is more resistant to fouling can use less energy, produce more output, and cost less to buy, operate, and maintain. Fouling in the U.S. petroleum refining industry is estimated to cost over $2 billion

annually. Also significantly affected are the chemical processing, pulp and paper, and electric utility industries.

Program goals are (1) to provide validated methodologies for the design and development of heat and mass transfer devices used in process industries, (2) to develop and apply new experimental techniques to enhance understanding of controlling heat and mass transfer processes, and (3) to identify and examine the technical feasibility of advanced and innovative industrial concepts. The program's relevance to U.S. industry has been marked over the last two years by the initiation of CRADAs with U.S. equipment manufacturers and end users, effectively doubling the program's size.

For the Office of Industrial Technologies, Argonne is also providing research and analysis in support of DOE's forest products industry strategy. Activities include preparation and summarization of information on research expertise in the field of forest products and an analysis of the capabilities of various participants.

f. Transportation (EE)

Argonne evaluates advanced transportation technologies, such as improved engines, energy-conserving components and systems, new materials, and alternative fuels (particularly innovative approaches to using methanol, ethanol, and natural gas in cars and trucks). In addition to technical feasibility, Argonne assesses economic and environmental effects of new transportation technologies. Argonne analysts project fuel consumption and environmental impacts for transportation systems under various technical and economic scenarios. These analyses suggest promising applications for advanced energy-conserving technologies and opportunities for technology transfer. For example, recent Laboratory analysis has shown that maglev trains have significant potential for intercity travel. The Laboratory has been granted six patents for innovative maglev designs based on its experimental work.

Argonne experiments have shown that particulates and smoke can be virtually eliminated from the emissions of diesel-fueled compression ignition engines by enriching the oxygen content of the air supplied to the engine through use of an air separator membrane. In FY 1996, this concept is being tested in a flexible-fuel passenger car capable of operating with 100% gasoline or a fuel mixture of up to 85% methanol. Initial results also show excellent decreases in emissions of carbon monoxide, hydrocarbons, and aldehydes, without significant increases in nitrogen oxides. In addition, the Laboratory has completed a study of the feasibility of applying oxygen enrichment to locomotive engines. This element of Argonne's Advanced Transportation Technology initiative (Section IV.A.7) is being pursued in a three-year experimental study organized as a CRADA with the Association of American Railroads.

Argonne is investigating the use of advanced materials as a way to reduce thermal and mechanical stresses in critical components of two-stroke engines, an engine type currently used in recreational boats and potentially applicable to automobiles. This work is being pursued under a CRADA with Mercury Marine, a major manufacturer of two-stroke engines.

Argonne has markedly expanded its assessments of future transportation technologies, particularly advanced and alternatively fueled vehicles. For the DOE Office of Transportation Technologies, the Laboratory has evaluated the costs and benefits of various rates of R&D spending and marketplace introduction for new transportation technologies.

In FY 1992 Argonne began using several types of alternatively fueled vehicles, becoming the first site in the nation to perform intensive "Level 2" data collection under the Alternative Fuels Motor Vehicle Act. The FY 1996 fleet at Argonne consists of 60 vehicles running on methanol, ethanol, and natural gas. Argonne is the only DOE site testing all fuels and models that are currently used in the federal fleet.

Argonne research is suitable for a variety of applications in light-duty and heavy-duty vehicles. The Laboratory is assessing magnesium and magnesium-based alloys for structural and body components to reduce

further the weight of light-duty vehicles. Advanced structural ceramics, such as silicon carbide and silicon nitride, and ceramic composites are being developed and evaluated for high-temperature applications in advanced power conversion units. New dielectric fabrication processes and materials are being developed for energy storage using ultracapacitors. Flywheel-based energy storage concepts and designs are being pursued for heavy-duty vehicles, notably locomotives, but they will also be applicable to energy storage for light-duty vehicles. Advanced synthetic liquid lubricants are being evaluated to determine their tribological compatibility at elevated temperatures with advanced ceramics and new surface coatings.

The Laboratory's work in the field of tribology (friction and wear) emphasizes a number of concepts specifically relevant to transportation. Most notable is the development and testing of ultrasmooth diamond and diamond-like carbon coatings that improve the wear performance of ceramics and steels under the severe loads and temperatures anticipated in new engine systems such as diesels and gas turbines. In addition, high-temperature (up to 1,000°C), lubricious, wear-resistant compounds (oxides, fluorides, and carbon-based compounds) are being evaluated and developed to improve the fuel efficiency of small, compact gas turbines for light-duty vehicles being developed for the Partnership for a New Generation of Vehicles (PNGV, a presidential initiative involving seven federal agencies and the Big Three automakers). Both advanced and conventional coating techniques (e.g., electroplating of nickel alloys) are being evaluated for corrosion and wear resistance when applied as low-cost polymer coatings that will be exposed to alcohol-based fuels. To improve manufacturing in the transportation industries, Argonne is developing electromagnetic forming of lightweight materials; evaluating cold and hot forming of lightweight alloys; and developing low-cost, environmentally benign solid lubricants for cold-forming steel and aluminum components for automobiles and heavier vehicles.

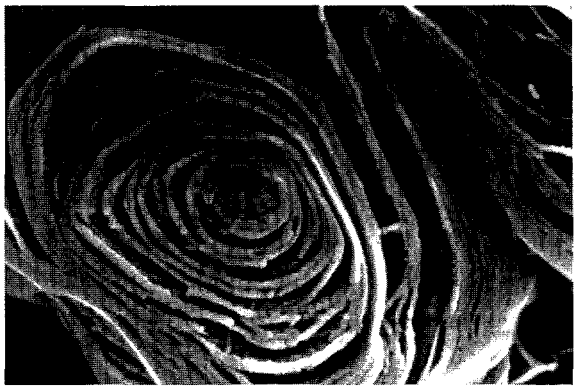


Figure V.9 Argonne scientists have developed boric acid as a self-replenishing lubricant for mechanical assemblies in transportation and other applications. Boric acid's unique layered-crystal structure accounts for its self-lubricating property. This photomicrograph illustrates the layered lubricant's crystallites. The rose-like appearance is created by stacked sheets of microcrystallites that become progressively smaller.

Argonne has played a key role in the PNGV, which aims to improve U.S. competitiveness in manufacturing, emissions, and fuel economy technologies. In the early stages of the PNGV, Argonne conducted technical analyses and led many initial planning efforts. The Laboratory is now assessing foreign technologies; analyzing transportation infrastructures; participating in many technology-specific PNGV teams; and organizing and participating in PNGV workshops on fuel cells, energy storage, and fuel processing.

Among the DOE laboratories, Argonne has one of the most diversified advanced battery research programs. Through the U.S. Advanced Battery Consortium (USABC, a partnership of the Big Three auto manufacturers and the Electric Power Research Institute), Argonne works with the private sector on the development of advanced batteries for electric vehicle propulsion. Work on lithium-polymer batteries, conducted under a USABC CRADA with 3M and HydroQuebec, includes testing and electrochemical characterization of cells, electrochemical modeling of cell processes and associated data acquisition, and development of

Figure V.10 This lithium-polymer battery prototype is being developed under a CRADA by Argonne, 3M, and HydroQuebec for the U.S. Advanced Battery Consortium. The prototype represents a light-weight, high-energy advanced battery system that is suitable for the next generation of electric vehicles.

new cathode material, as well as design of full-scale electric vehicle batteries. The Laboratory is also investigating high-temperature batteries (lithium-iron disulfide and sodium-nickel chloride) and ambient-temperature systems (such as lithium-ion, nickel-metal hydride, and various ultracapacitor systems). Laboratory staff use Argonne's Electrochemical Analysis and Diagnostics Laboratory to conduct full-scale tests for USABC on batteries developed in the private sector and postoperative analyses of failed battery cell components. Results from the Argonne Electrochemical Analysis and Diagnostics Laboratory have helped developers to qualify and improve the performance of their batteries. In FY 1995 this facility was cited for excellence by DOE, USABC, and private companies.

In fuel cell research, Argonne is pioneering technology for converting hydrocarbon fuels to hydrogen-rich gas, directly on board vehicles. Exploiting the principle of partial oxidation, the Laboratory is developing compact, lightweight processors for gasoline, in close coordination with the development of fuel cell vehicles at General Motors. For solid oxide fuel cells, the Laboratory is exploring new materials that will allow substantially lower operating temperatures, an approach that is very promising for heavy-duty applications in trucks and buses. The Laboratory is also investigating anion-exchange membranes as electrolytes for fuel cells operating directly on methanol; this concept promises to overcome many limitations of conventional polymer-electrolyte methanol fuel cells, such as the methanol crossover problem. In addition, the Laboratory is modeling and analyzing fuel cell systems as part of DOE's contribution to the International Energy Agency project on fuel cells.

Argonne supports the Office of Transportation Technologies in technical management of its fuel cell R&D contracts with General Motors, Ford, and Chrysler. In 1995, the Laboratory began to develop a DOE fuel cell test facility to conduct independent tests of fuel cell stacks from various industrial developers. At the same time, the Laboratory has led efforts to develop standardized procedures for evaluating fuel cells.

Argonne research on nondestructive characterization of new ceramic and metal-matrix composite materials for transportation systems aims to improve processing and usage of the materials. Work will continue on the reliability of advanced methods using X-rays, lasers, and nuclear magnetic resonance, infrared, and acoustic techniques. Other applicable approaches include the use of microwaves, millimeter waves, and neutron diffraction.

Argonne is identifying materials-related research needed to develop a more durable, fuel-efficient heat engine and a lighter vehicle body for automobiles. Results will help DOE structure a complementary R&D program. Argonne will assist in identifying materials-related research needs for a lightweight, aluminum-intensive passenger car by conducting a field evaluation of an experimental prototype supplied by a major U.S. automaker.

Related to the PNGV is the Future Car Challenge, a vehicle engineering research

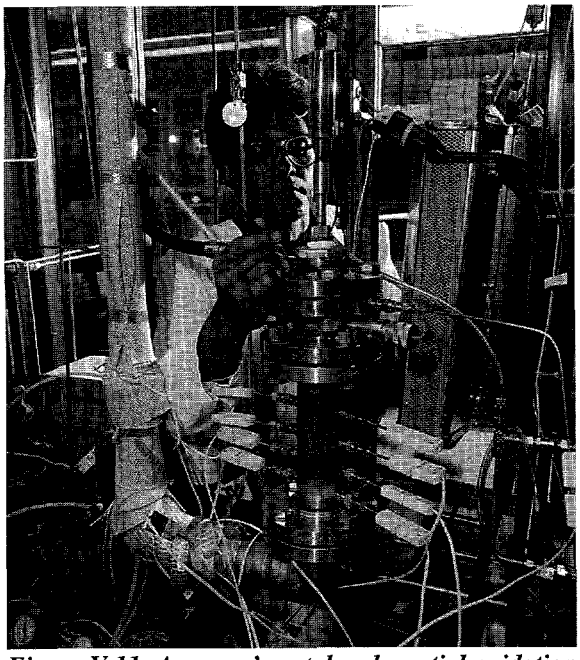


Figure V.11 Argonne's catalyzed, partial-oxidation methanol reformer, shown here on a test stand, is suitable for fuel cell systems in light-duty vehicles.

competition for university teams focusing on incorporating advanced technologies in midsized cars to meet PNGV goals. Jointly with the U.S. Council for Automotive Research, Argonne will organize and manage this competition. For FY 1996 and FY 1997, a competition involving propane fuel technology is planned.

g. Technical and Financial (EF)

Argonne assists the Technical and Financial Assistance Office in two areas: (1) evaluating the impacts of specific programs or projects (such as evaluating Institutional Conservation Programs or third-party financing of multifamily buildings) and (2) providing technical assistance to regional DOE State and Local Program offices (for example, holding conferences, conducting feasibility studies, and speaking at regional meetings).

h. In-House Energy (WB)

The DOE In-House Energy Management Program supports activities that enhance energy management at the Laboratory. These activities include studies of the energy efficiency of existing buildings and the cost-effectiveness of possible improvements, actual retrofitting of existing buildings, and improvements in the efficiency of central plant systems.

4. Fossil Energy

a. Overview

The DOE Office of Fossil Energy is consolidating its research, development, and demonstration activities under two business lines: (1) coal and power systems and (2) natural gas and petroleum technology. Within those business lines, five specific product lines have been identified: (1) power systems, (2) environmental systems, (3) coal fuels and industrial systems, (4) upstream exploration and production, and (5) downstream processing.

The Office of Fossil Energy is expected to continue its emphasis on industrial collaboration. Argonne participates in several CRADAs and other industrial collaborations on fossil energy research. Major objectives include improved processing of heavy petroleum crudes and residua, more efficient conversion of natural gas to syngas and other valuable chemicals, and development of a new generation of simulators for petroleum and natural gas reservoirs.

The DOE Computational Technology Program, supported by several secretarial offices, focuses on exploration and development for oil and gas. Argonne is conducting one of the projects in this area.

In response to DOE's evolving goals and objectives in fossil energy, Argonne conducts R&D on specific technologies for energy production, conversion, and utilization. The Laboratory also contributes to relevant basic science and to analysis of regional, national, and global environmental issues including acid

precipitation, air toxics, global climate change, and wetlands management.

b. Current Programs (AA, AB, AC, AU, AW, and AZ)

Argonne's R&D in fossil energy covers a wide spectrum, including environmental control technology; advanced technology in materials, transport, and multiphase flow; liquefaction, especially novel conversion from natural gas; wetlands and waste management for oil producers; fuel cells; upgrading of heavy crude oil and residuum; gas recovery, transport, use, and tracking; and environmental discharges.

Argonne's work in environmental control technology has emphasized the development, testing, and evaluation of new processes at laboratory scale, followed by large-scale tests of the most promising concepts. Current research focuses on improving techniques for controlling hazardous air pollutants ("air toxics"), such as mercury, that are emitted when fossil fuels are burned. The Laboratory is developing sorbents based on chemical treatment of low-cost substrates as a more economical alternative to activated carbon for injection into power plant ductworks; in addition, Argonne's flue gas cleanup laboratory has studied the performance of several proprietary sorbents in collaboration with private industry. At the same time, the Laboratory is studying techniques for enhancing the removal of mercury in wet scrubbers by converting the mercury to more soluble chemical forms. Other work addresses the sources and sinks of mercury emissions; relative risks from utilities' emissions of hazardous air pollutants; and impacts from flue gas cleaning on emissions of air toxics, discharges to water, and generation of solid wastes.

Argonne is working in cooperation with filter vendors to investigate pulse cleaning and material behavior for ceramic-membrane dead-end filters and advanced ceramic candle filters. Analytical models are being developed to determine fluid mechanics and particle transport during filtration and reverse gas cleaning. Specimens exposed for extended periods (over 2,000 hours) to coal ash, alkali, and contaminants are evaluated for changes in physical and thermomechanical properties and microstructure. Theoretical models and experimental data are used in conjunction to predict survivability of filters under conditions anticipated in commercial service.

Argonne's work in advanced research and technology development focuses on three areas: materials, energy transport processes and mechanisms, and multiphase flow. In the area of materials applicable to advanced technologies for coal conversion and combustion, the Laboratory continues to develop (1) improved ceramics and ceramic-based composites, along with nondestructive techniques for evaluating ceramics at various stages of processing, and (2) improved metals and alloys.

Argonne's research on structural ceramics will continue to emphasize development of nondestructive evaluative methods and the effects of flaws on fracture behavior. Metals research will continue to focus on gaseous corrosion of alloys, with emphasis on the development of protective scales and their effects on mechanical properties.

Argonne continues to investigate ways to quantify and mitigate the loss of wetlands associated with petroleum and gas production and transport. This issue has become very important in the production-rich coastal areas of the Gulf of Mexico and in other wetland ecosystems across the nation.

The Laboratory is providing technical support for a field demonstration to evaluate technologies for the control and disposal of naturally occurring radioactive materials (NORM). At present, few waste management facilities will accept NORM wastes, a difficulty impairing the development of U.S. petroleum resources, especially in the Gulf Coast region. For the field demonstration, Argonne is developing a site quality assurance plan and a project health and safety plan, guiding the development of risk assessments, and providing technical oversight.

In support of the DOE-Fossil Energy fuel cell utility program, Argonne is investigating technological issues important for industrial development. For solid oxide fuel cells, relationships between (1) interfacial geometry

and composition and (2) electrochemical overpotential are being explored. For molten carbonate technology, the Laboratory is investigating electrolyte segregation in operating cells, as well as bipolar plate corrosion as a function of potential gradients. The Laboratory is also developing improved cathode materials under a direct contract with MC-Power and is exploring new fabrication methods for solid oxide fuel cells under a contract with the Electric Power Research Institute. The military is interested in sealants developed earlier by the Argonne program, for use in oxygen purification devices; manufacturers will be testing the material.

DOE's Advanced Extraction and Process Technology Program, managed by the Bartlesville Project Office, has selected Argonne to participate in five CRADAs with industrial collaborators to develop better technologies for upgrading heavy crude oil and residuum. These R&D projects are addressing the detection and mitigation of fouling on heat exchange surfaces; application of nuclear magnetic resonance to on-line sensors in process environments; and improved processes for upgrading residuum, through application of fluidized-bed reactors, improved catalysts, and better understanding of feedstock chemistry. Industrial partners include Amoco, Chevron, California Syncrude, and the Heat Transfer Research Institute.

Argonne is helping the Office of Fossil Energy wind down its proof-of-concept program for magnetohydrodynamics by performing environmental assessments of several sites used in the DOE program (to identify compliance and restoration issues associated with their transfer) and by assisting in the disposition of equipment stored at the Laboratory.

In support of the Office of Fuels Programs, Argonne has developed a personal-computer-based model of the U.S. natural gas system. The model combines a powerful geographic information system with an extensive database of technical, financial, and regulatory information on more than 2,500 natural gas companies, including interstate and intrastate pipelines, local distribution companies, producers, marketers, and end users. Recent applications include analyses of natural gas trade with Canada and Mexico.

In support of the Office of Planning and Environment, the Laboratory has focused on assessment of visibility issues related to man-made pollution, particularly in the western United States. A formal model was developed, along with baseline energy and emission trends. This work has emphasized the specification of transfer coefficients that link source emissions to atmospheric concentrations and depositions at receptor sites.

Argonne continues to analyze greenhouse gas emissions and global climate change. Specific areas of emphasis include federal policies and positions, response strategies, and policy instruments such as carbon taxes. The Laboratory has investigated clean coal technologies and their potential impact on energy systems and the environment, by using life cycle analyses to compare the economics of electricity generation technologies and to evaluate alternative tax and permitting incentives for new technologies.

Initiative: Ion Transport Membranes for the Production of Synthesis Gas from Natural Gas

In cooperation with Amoco, Argonne has developed at bench scale a revolutionary new technology that promises to reduce significantly the cost of converting natural gas into liquid fuels, hydrogen, and high-value chemicals. Termed ITM Syngas (for Ion-Transport-Membrane Synthesis Gas), the new technology combines into one simple operation the separation of oxygen from air and the conversion of natural gas into syngas, thereby eliminating the need for an oxygen plant and significantly reducing the energy and capital cost of syngas production. This feat is accomplished through the use of novel, solid, mixed-conducting oxide ceramic membranes that conduct both oxide ions and electrons through their lattice structures at elevated temperatures.

Significant technical challenges remain before the commercial viability of ITM Syngas technology is proven. Basic research must be translated into viable membrane shapes and

reactor designs that can be scaled up and integrated into robust, workable systems exhibiting performance like that observed at laboratory scale. Amoco and Air Products and Chemicals have proposed that the technology be advanced with Argonne through a fully integrated unit at the proof-of-concept scale, funded in part by DOE. The overall cost of the initiative is estimated to be about $34 million, which is to be shared among the participants. Argonne's research activities are estimated to require approximately $5 million over five years (see Table V.9). Funding is sought from Fossil Energy-Gas Utilization (AB-05).

Table V.9 Ion Transport Membranes for the Production of Synthesis Gas from Natural Gas
($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	0.5	1.2	1.3	1.0	0.4	-	-
Capital Equipment	-	0.8	-	-	-	-	-
Construction	-	-	-	-	-	-	-
Total	0.5	2.0	1.3	1.0	0.4	-	-
Direct Personnel	1.0	6.0	6.1	4.2	1.6	-	-

Argonne's contributions to this partnership will focus on the development, synthesis, characterization, and testing of robust dense-phase ceramic components, including critical seals and transition materials. Testing will include multiple thermal and pressure cycles, to establish probable lifetimes and reliability of materials in commercial service. Reactor module designs will emphasize ease of fabrication and minimal commercial cost.

Beyond supporting the development of ITM Syngas technology, this initiative will enhance Argonne's growing capabilities in advanced ceramics, which underlie several of the Laboratory's core competencies (see Section II.B). Related Argonne research is addressing ceramics-based high-temperature superconductors, fuel cell components, and membranes that are selectively permeable to molecules or ions other than those relevant for ITM Syngas.

5. Defense Programs

Argonne provides technical and analytical assistance to the Office of Defense Programs in support of federally mandated activities relating to emergency management and preparedness. A significant part of this support involves analysis of policy requirements promulgated by Presidential Executive Orders 12656 and 12856; the Superfund Amendments and Reauthorization Act of 1986, Title III; Titles 10, 29, 40, and 49 of the *Code of Federal Regulations*; the Federal Response Plan; and DOE orders and emergency management guides. In addition, Argonne assesses emergency preparedness exercises directed toward emergencies involving radioogical, chemical, and hazardous materials. The Laboratory also trains controllers and evaluators for these exercises. Other support requires working directly with DOE field elements, assisting in the development of effective emergency management and preparedness programs, and assessing the effectiveness of these programs at selected sites.

Along with other DOE national laboratories, Argonne is a major participant in the congressionally mandated Newly Independent States — Industrial Partnership Program. This collaboration with defense institutes of the former Soviet Union is pursuing the development of commercial technologies. Under the auspices of the collaboration and in cooperation with selected partners in U.S. industry and in the newly independent states, Argonne also participates in other technology development projects endorsed by DOE, the U.S. Department of State, and the U.S. Industry Coalition.

6. Nonproliferation and National Security

Argonne's multidisciplinary work in the field of arms control verification and nonproliferation is coordinated within a single Laboratory program that is closely integrated with the DOE Office of Nonproliferation and National Security. As superpower tensions

diminish, emphasis shifts toward nonroliferaion, focusing on four major program areas: arms control and nonproliferation policy and technology, low-enrichment research reactor fuel, export control, and international safeuards.

a. Nonproliferation and Verification Research and Development (GC)

The Office of Research and Development within the DOE Office of Nonproliferation and National Security supports Argonne's development of several new technologies to detect potential nuclear proliferation and to monitor compliance with treaties in force or pending. These technologies include using various novel types of tags and seals, as well as satellite tracking, to protect and monitor sensitive materials; a crystal lens for sensitive detection of gamma radiation; millimeter wave detection of chemical effluents from handling of special nuclear material and production of chemicals prohibited under the Chemical Weapons Convention; a miniature time-of-flight mass spectrometer to identify chemical or nuclear effluents; a sealed-tube neutron generator for nondestructive examination of munitions and other sealed containers; and computer techniques to automate and expedite the handling and interpretation of data from national verification programs.

Argonne participates in a special program that focuses on developing advanced concepts and new programs. The Laboratory's advanced concepts program is analyzing new verification techniques and technologies, including advanced systems for detecting chemical effluents from activities potentially related to nuclear proliferaion and for verifying compliance with the Chemical Weapons Convention, novel radiological instruments for detecting fissile or chemical materials, techniques for monitoring nuclear reactor operations, and radar techniques for detecting underground structures.

Argonne participates in a DOE program that brings teachers from local secondary schools, especially in disadvantaged areas, to the Laboratory during the summer to work with staff scientists on research projects related to nonproliferation and national security. The teachers gain detailed technical knowledge and insights into scientific research methods. The teachers also interact with each other and develop plans for new classroom lessons. In 1995, the teachers created a home page on the World Wide Web, as did some of their schools.

In the area of arms control and nonproliferation policy analysis, Argonne is studying various arms control treaties to elucidate legal aspects of their implementation. The Laboratory studies procedures for determining host compliance during inspections under the Chemical Weapons Convention and the Strategic Arms Reduction Treaty. Argonne performed a series of studies comparing U.S. and Russian traditions, customs, and practices related to arms control and nonproliferation issues. The Laboratory provides Russian-English translaions for meetings in Moscow and for documents related to arms control and nonproliferation.

b. Low-Enrichment Research Reactor Fuel

The DOE Office of Arms Control and Nonproliferation supports Argonne's Reduced Enrichment for Research and Test Reactors (RERTR) program. This program has developed new fuel systems that can make research and test reactors throughout the world more resistant to proliferation, primarily by reducing the degree to which the fuel is enriched. To this end, Argonne assists operators of research reactors who wish to convert to low-enrichment fuels and analyzes the safety, performance, and economic characteristics of reactors using such fuels. One joint study of this kind, with the operator of the SAFARI-1 reactor in South Africa, was completed in FY 1995.

Argonne is working with the Research and Development Institute of Power Engineering in Moscow to complete the Russian reduced-enrichment program, which began in 1978 but was halted because of lack of funding in 1988-1989. Under an Argonne contract signed in January 1995, the Russian organization will develop and test high-density fuels and perform whole-core demonstrations of the use of these fuels in two research reactors of Russian design. Successful completion of this five- to six-year

program will provide the technical means to convert to low-enrichment fuels more than 20 research reactors in Russia, other republics of the former Soviet Union, Eastern Europe, Libya, North Korea, and Vietnam.

The cornerstone of the RERTR program is the application of a new technology based on silicide dispersion fuels that have been developed, tested, and demonstrated under the auspices of the program. High uranium densities allow most research and test reactors to use the low-enrichment uranium fuel without significant reductions in performance or increases in cost. Development of one of the silicide fuels (uranium disilicide) is virtually complete. Demonstration of whole cores in the Oak Ridge Research Reactor, using commercially fabricated uranium disilicide fuel elements, has been completed. Argonne is developing an irradiation behavior model for this fuel, to support the fuel's application in both existing and new research reactors. DOE has announced that it will begin in March 1996 to fund the development of fuels having even higher density.

The RERTR program is also working toward the development of low-enrichment uranium targets and processes for production of molybdenum-99. These targets, which support very important medical applications, currently use high-enrichment uranium and require significant exports of that material from the United States to countries around the world. One of the target systems is being tested in cooperation with the National Atomic Energy Agency of Indonesia under a cooperation agreement signed in November 1994.

c. Export Control

For the Export Control Division of the DOE Office of Nonproliferation and National Security, Argonne conducts several projects in the area of nuclear technology security in support of DOE's statutory responsibilities under the Atomic Energy Act of 1954 (as amended), the Nuclear Nonproliferation Act of 1978, and U.S. treaty obligations emanating from the Treaty on the Non-Proliferation of Nuclear Weapons. These projects contribute to controlling dissemination outside the United States of certain unclassified equipment, materials, and scientific and technical information that could contribute to nuclear proliferation. Laboratory technical analyses and expertise support (1) review and evaluation of nuclear and nuclear-related exports; (2) development and maintenance of a database on technical assistance provided in support of the Treaty on the Nonproliferation of Nuclear Weapons; (3) U.S. participation in multilateral export control regimes; (4) identification, definition, and control of sensitive equipment, materials, and technologies; (5) maintenance of a system for tracking foreign requests for information from DOE laboratories; and (6) sensitizing DOE and DOE contractor personnel to proliferation concerns and to technology security.

Argonne participates in projects supported by DOE or the Department of Defense that assist states of the former Soviet Union (FSU) with establishment of national systems for identifying and controlling equipment and technologies that could be used for the design, production, or testing of weapons of mass destruction. As part of FY 1995 government-to-government activities under the Cooperative Threat Reduction (Nunn-Lugar) Act, Argonne contributed technical support for briefings to government officials in Ukraine and Kazakhstan on national and international export control issues. Future activities will include assisting these FSU countries and others in (1) establishing technical support infrastructures for government policy, licensing, and enforcement authorities; (2) organizing FSU technical experts to develop export review processes; and (3) establishing technical collaborations promoting protection of weapons technologies.

d. International Safeguards

Argonne works for the Russia-Newly Independent States (NIS) Nuclear Material Security Task Force of the DOE Office of Nonproliferation and National Security. The focus is support for U.S. assistance in safeguarding nuclear materials and facilities that

are not directly associated with nuclear weapons in the NIS. Under the Cooperative Threat Reduction Act, the Defense Nuclear Agency provides funding for upgrades of material protection, control, and accountancy (MPC&A) at selected facilities in Ukraine, Kazakhstan, and Belarus. The Task Force also supports assistance to other facilities in those countries and to nuclear facilities in other of the NIS. Argonne coordinates management of technical support through a project involving multiple divisions at Argonne, as well as four other DOE laboratories. To date, Argonne technical support has included MPC&A site surveys for selected nuclear facilities in Ukraine, Belarus, Latvia, Lithuania, Uzbekistan, and Kazakhstan; participation in visits by NIS policy and technical representatives to Argonne and other U.S. facilities; design of proposed MPC&A upgrades for NIS facilities; coordination of upgrades by other donor states; and development of personal computer software for material control and accountability.

7. Environmental Management

Argonne supports the Office of Environmental Management in both defense and non-defense areas.

a. Defense Environmental Management (EW)

Argonne's work on defense waste management technology is conducted for the DOE programs in high-level and low-level waste technology, interim waste operations, hazardous chemical defense waste, and decontamination and decommissioning (D&D) operations. Argonne also performs technical analyses of environmental compliance and remedial investigations at DOE sites and develops criteria for prioritizing DOE efforts to reduce waste and clean up existing problems.

Argonne's work on high-level waste technology involves helping DOE to address technical issues related to starting up waste processing facilities at the Savannah River and West Valley sites. Argonne is performing a series of long-term tests using glass fabricated from Savannah River Plant waste products. This glass is highly radioactive, and all testing is done remotely. The tests will (1) demonstrate the comparability of the physical and chemical behavior of the actual vitrified wastes and the simulated glass waste, (2) evaluate the effects of high radiation levels on glass performance, and (3) establish the performance of glass under long-term repository storage conditions. As part of this effort, Argonne has successfully used analytical electron microscopy to determine mechanisms of reactions in glasses and to describe actinide-bearing colloids that form from the glass and are suspended in solution. Argonne is conducting experiments that will help define the relative importance of small colloidal particles in the release of actinides from a repository.

Argonne's work in support of high-level waste disposal also includes experimental programs that examine the performance of simulated waste forms under conditions that mimic a deep geologic repository, in terms of moisture flow, temperature, and contact with various materials. Data revealing the chemistries and kinetics of relevant processes will be useful for the ultimate objective of licensing a repository. Recent work has focused on the candidate repository at Yucca Mountain in Nevada.

Argonne is developing the following new technologies for the Office of Science and Technology (OST) within the Office of Environmental Management: (1) a combined TRUEX (TRansUranic EXtraction) and SREX (StRontium EXtraction) process to extract and selectively partition uranium, transuranics (neptunium, plutonium, and americium), strontium-90, and technetium-99 dissolved in waste sludge; (2) *in situ* immobilization using phosphate mineralization of actinides; (3) *in situ* magnetically assisted chemical separations; (4) immobilization (vitrification) of ion-exchange resins after use for cesium removal from high-level tank waste; (5) a plasma hearth process for destroying mixed and transuranic wastes; (6) ultrasonic sensors for measuring fluid viscosity and percent of solids (by volume); and (7) innovative processes for

Figure V.12 Argonne researchers developed CERAMICRETE, a low-cost ceramic binder, to stabilize and solidify hazardous and radioactive waste. Here a test drum of simulated waste is inspected. CERAMICRETE has potential for other important applications, such as converting non-hazardous wastes into useful construction products. The new technology won an R&D 100 Award in 1996.

treating hazardous, mixed, and radioactive materials in soil and groundwater.

Other work for OST involves analytical chemistry and characterization: (1) radio-analytical methods evaluation, (2) development of Fourier transform infrared spectroscopy as a continuous emissions monitor for incineration, (3) development and evaluation of a fluid-based apparatus for removing radon from offgas streams at the Fernald Environmental Management Vitrification Facility, (4) glass testing and evaluation for the minimum-additive waste stabilization (MAWS) process, (5) study of the glass compositional envelope for MAWS, and (6) evaluation of the management and performance of analytical laboratories.

Two major efforts at Argonne supported by OST are pilot-scale testing of the plasma hearth process and a large-scale demonstration project involving D&D of the CP-5 Reactor. The plasma hearth process is a modification of one commercially available for metals processing but not yet demonstrated for the treatment of mixed wastes. A radioactive bench-scale system at Argonne-West will be used to test this approach for treating radioactive waste and to provide an assessment of radiological and operational performance.

The CP-5 Reactor at Argonne-East will host one of the first large-scale demonstrations in DOE's focus area of D&D. The demonstration will include removal of the reactor's internal components, removal of the biological shield, decontamination of the fuel rod storage area, decontamination of radioactive material storage and handling facilities (including the fuel pool), and decontamination and dismantling of the building.

The TRUEX process, invented at Argonne, removes, separates, and recovers transuranic elements from waste streams of the kind generated and stored at DOE facilities. The treated waste then qualifies as nontransuranic, alleviating the need for long-term storage, making unnecessary deep disposal of the bulk of the waste, and allowing recovery of plutonium that otherwise would be lost. Overall, TRUEX will reduce disposal costs very substantially. Argonne is now developing applications, flow sheets, and tests for the TRUEX process. Application of centrifugal contactors to the process is also being investigated.

Building on work funded by the Department of Agriculture and the Department of the Interior, Argonne is investigating ways that its Expedited Site Characterization process can aid DOE-Environmental Management. This methodology for characterizing sites for possible remediation has greatly decreased costs, the time required for characterization, and the need for intrusive activities in the field.

DOE's responsibilities for overseeing the transportation of hazardous and nuclear material

have recently taken on new importance, particularly the responsibility for shipment of defense wastes and spent nuclear fuel. In addition, Argonne provides generic technical assistance to DOE on the development of department-wide transportation regulations and on issues associated with fleet transportation, traffic management, public relations, and state-of-the-art electronic systems for tracking shipments.

Argonne is supporting the Office of Environmental Restoration in a number of areas, including developing cost information for restoration activities, evaluating data on contaminated media at DOE facilities, analyzing information on compliance agreements for federal facilities, and implementing environmental information systems.

Argonne is also participating in the Technology Connection Program sponsored by the Office of Environmental Restoration, seeking to bring technologies from the public and private sectors to serve high-priority DOE remediation needs. At the same time, Argonne will formally evaluate (following defined quality assurance and control procedures) results from technology demonstrations to determine their applicability at other DOE sites having different conditions and to facilitate implementation of these technologies where appropriate.

Argonne is evaluating the human health risks, environmental impacts, and sociopolitical impacts associated with alternative methods of recycling radioactive scrap metal. Results help DOE to assess recycling opportunities and management alternatives.

Argonne is also studying seismic response in underground storage tanks for high-level waste. Experimental test results are being compared to computer simulations to study the seismic response of thin-walled tanks to sloshing, by using a computer code previously developed by the Laboratory in its work on nuclear energy. The experimental tests are being conducted by Japan's National Research Institute for Earth Science and Prevention on tanks of different shapes, filled to different levels and containing fluids having various viscosity values. In expanding work, Argonne is studying the effects of fluid impact against tank roofs during seismic events.

Technical support and programmatic assistance are being provided in the review of implementation plans and safety analysis reports prepared in compliance with DOE Order 5480.23, by various facilities under the cognizance of the Office of Waste Operations. Argonne is also supporting the review and evaluation of regulations that affect waste management at DOE facilities.

Argonne participates in the DOE Spent Nuclear Fuel Program (1) through membership on technical working groups addressing fuel inventories; facilities for storage, characterization, and conditioning of spent nuclear fuel; and fuels for foreign research reactors and (2) through the development of technology for the safe interim storage, conditioning, and eventual disposal of spent nuclear fuel. In addition, Argonne has contributed to assessments of environment, safety, and health vulnerabilities associated with storage of these materials. The Laboratory has developed site-specific plans for activities related to spent nuclear fuel.

Compliance with the National Environmental Policy Act has been a major focus of the DOE Spent Nuclear Fuel Program. An environmental impact statement was prepared for the return to the United States of research reactor fuels that originated in this country. Argonne contributed its expertise on those fuels. The Laboratory is also providing transportation analyses and contributing to the programmatic environmental impact statement for the entire DOE spent nuclear fuels complex.

Argonne anticipates further participation in the DOE Spent Nuclear Fuel Program. Characterization facilities at both Argonne sites are important resources for this work. Furthermore, the electrometallurgical treatment technology being developed at Argonne has potentially important application in conditioning many types of spent nuclear fuel for eventual geologic disposal. This technology is intended for initial demonstration at Argonne-West with irradiated Experimental Breeder Reactor-II fuel and blanket assemblies in the Fuel Conditioning

Facility, pending completion of environmental reviews.

Contact-handled transuranic and alpha low-level mixed waste requires characterization to meet state and federal requirements under the Resource Conservation and Recovery Act and the Federal Facilities Compliance Act. Characterization of waste is also required for performance assessment modeling needed to open DOE's Waste Isolation Pilot Plant as a permanent disposal facility. Currently, over 130,000 containers of this type of waste are stored for retrieval at the Radioactive Waste Management Complex operated by Lockheed Idaho Technologies Company. To provide needed waste characterization capabilities, Argonne-West has developed the Waste Characterization Area, a new facility within its Hot Fuel Examination Facility. Approximately 90 drums of waste will be characterized and repackaged in the facility each year. Characterization entails collecting gas samples from various regions within the drum and the waste matrix, removing and visually examining waste contents, measuring or estimating various physical parameters, and repackaging the waste into a new drum.

Argonne is developing advanced information systems for two other groups. For the Regulatory Compliance Division, the Laboratory is developing site visualization software for programmatic environmental impact statements. This software provides time-based displays of DOE facilities and their environments. For the Office of Nuclear Material and Facility Stabilization, Argonne is developing a consistent database describing all the facilities of DOE-Environmental Management.

b. Non-Defense Environmental Management (EX)

As part of the Formerly Utilized Sites Remedial Action Program, Argonne assists in developing, applying, and evaluating approaches for assessing former sites of the Manhattan Engineer District and the Atomic Energy Commission that handled radioactive materials, in order to determine the potential for risk to public health and safety and whether decontamination is needed. Argonne also supports cleanups by conducting and reviewing environmental analyses associated with these sites. Also under this program, Argonne maintains surveillance on sites (known as Site A and Plot M) in Palos Forest Preserve southwest of Chicago.

For surplus DOE facilities like those at the Weldon Spring and Fernald sites, Argonne is developing alternative strategies and plans for cleanup and assessing potential health risks and environmental impacts. The Laboratory is also supporting development of cleanup approaches for such sites. Environmental review and support are also provided for cleanups under the Surplus Facilities Inventory and Assessment program.

Argonne is supporting the Environmental Restoration Office of Northwestern Area Programs in the development and implementation of quality assurance programs, in self-assessment and management evaluations, and in implementation of safety and health programs. The Laboratory also analyzes economic impacts and risks to human health and the environment posed by inactive and surplus DOE facilities and sites in the Northwestern Programs Area. In addition, Argonne is analyzing legislation, regulations, and policies; interpreting DOE policy and guidance for successful implementation of federal environmental laws; and monitoring and providing technical advice on responses to federal and state regulations dealing with residual radioactivity levels in soils and scrap metals.

Future work in this area will expand because of cleanups at virtually all major DOE sites, including Argonne. Environmental restoration at the Laboratory includes remediation of the 800 area landfill, the 317/319/east-northeast area, and numerous other sites. Major decontamination and decommissioning of unused facilities are also underway at Argonne's Illinois site. These facilities include the CP-5 Reactor, the Experimental Boiling Water Reactor in Building 331, and several hot cell facilities located across the Laboratory. At completion, the facilities will be available for unrestricted use. Argonne staff will also support environmental restoration activities

at other DOE sites, such as Brookhaven National Laboratory and the Rocky Flats Environmental Technology Site. In addition, the Laboratory will be devoting major efforts to upgrading its waste management operations by, for example, rehabilitating the waste management building; upgrading the hazardous, radioactive, and mixed waste storage facility; and minimizing generation of regulated waste.

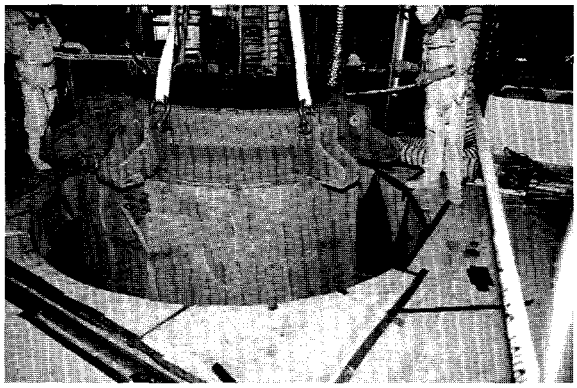


Figure V.13 Argonne's Experimental Boiling Water Reactor operated from 1956 to 1967. Decontamination and decommissioning (D&D) work on the reactor is part of a Laboratory program to develop D&D technologies that are more effective and less costly. (See also Section V.A.1.b.)

8. Environment, Safety, and Health (HA)

Argonne's work for the Assistant Secretary for Environment, Safety, and Health provides technical support in developing data, analyses, guidance, and training that can be used by DOE facilities to ensure their compliance with environmental, safety, and health regulations. The Laboratory also conducts research relevant to the effects on workers of radiation and other toxic and hazardous materials.

Argonne's activities in guidance and compliance are supported by DOE under Environment, Safety, and Health: Overview and Assessment (HA-01). Environmental data assembled, evaluated, and applied by Argonne support sound DOE planning for environmental protection, safety, and emergencies.

Argonne will be assisting the DOE Office of Environment, Safety, and Health in areas related specifically to regulation of its internal facilities. For the Environmental Guidance Office, Argonne is developing data, analyses, and training materials and courses that can be used by DOE facilities to ensure their compliance with state and federal environmental regulations. The Argonne RESRAD model is being further developed for use as a primary tool in determining cleanup requirements and in assessing human health risk for radioactively and chemically contaminated soils and buildings. Argonne's extensive experience with the requirements of the National Environmental Policy Act (NEPA) is utilized by the DOE NEPA Project Assistance Office in developing guidance and reviewing NEPA documents prepared specifically for DOE. The Laboratory will also provide general technical assistance, particularly regarding past and present practices for disposing of hazardous wastes, and will help to develop strategies and procedures to streamline the cleanup process.

Argonne assists the DOE Office of Facility Safety Analysis, Division of Transportation and Packaging Safety, by reviewing safety analysis reports for packaging (SARPs) and providing training in quality assurance and other areas. An independent Argonne group reviews SARPs and provides technical support to DOE's centralized packaging certification program.

Argonne recently completed an environmental impact statement for the Western Area Power Administration's electric power marketing programs in the Colorado River Storage Project Customer Service Office. Operations of hydroelectric facilities in the Colorado River Basin were studied to evaluate environmental impacts to natural resources downstream and economic impacts to Western's power customers resulting from changes in dam operations. The analysis included assessments of air quality, ecological resources, hydrology, and cultural resources, as well as economic and power systems studies of electricity demand, expansion planning, demand-side management, and recreation and tourism. Follow-up activities include a monitoring program.

For the Office of Information Management, Argonne continues to develop a hypertext information management system that serves as a central repository for ES&H and NEPA oversight documents. The system functions as a management planning and decision-making tool that facilitates analysis; it also encourages technology transfer and the communication of lessons learned across DOE. The system is accessed by DOE program offices, field offices, and the public through local area networks and the Internet.

For the Office of Human Radiation Experiments, Argonne has developed an innovative information management system that provides on-line public access to reports pertaining to human radiation experiments. (As a part of the Openness Initiative of the Secretary of Energy, DOE has recovered information on experiments dating back to 1945.) Over 250,000 pages of reports are available over the Internet via the World Wide Web, with images and searchable text linked together. Agencies other than DOE are also placing information on human radiation experiments into this system.

Argonne assists other DOE assistant secretarial offices with technical expertise on environmental issues affecting their programs (which are discussed elsewhere in this chapter of the *Institutional Plan*). For example, as part of the programmatic environmental impact statement for DOE's science-based Stockpile Stewardship and Management Program, Argonne is analyzing potential environmental impacts from constructing and operating alternative designs for the National Ignition Facility at one of four sites.

Initiative: Assessment and Management of Risk

Argonne proposes an initiative in risk assessment and risk management that builds on and consolidates the Laboratory's extensive, diverse expertise in health and safety studies and related studies of system failures. Using a common base of risk evaluation methodologies, the resulting comprehensive program will address scientific and engineering investigations of hazards and other sources of risk; the pathways and mechanisms by which sensitive humans, ecologies, and other systems become exposed; and the nature and extent of the impacts resulting from exposure. Also included will be risk management and related processes of communicating risks to decision makers and affected communities.

This initiative will support Argonne's broader missions in the development and technical evaluation of energy and environmental technologies, in areas such as accident and safety analyses, risk-based maintenance for nuclear power plants and other engineered facilities, and transportation of hazardous materials. Risk assessment is increasingly understood to be an appropriate basis for formulating cost-effective policy decisions on issues ranging from protection of the environment to the allocation of resources for technology development.

Resources required are described in Table V.10. Funding is sought from the Environment, Safety, and Health Program (HA) and also from the Environmental Management programs (EW and EX). No significant NEPA-related impacts or costs are anticipated.

Table V.10 Assessment and Management of Risk
($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Costs							
Operating	0.7	1.0	1.5	2.5	3.0	3.0	3.0
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	-	-	-	-	-	-	-
Total	0.8	1.1	1.6	2.6	3.1	3.1	3.1
Direct Personnel	4.0	5.1	7.1	11.0	12.0	12.0	12.0

9. Civilian Radioactive Waste Management (DB)

Argonne provides administrative, management, and technical assistance to the Office of Civilian Radioactive Waste Management, principally regarding environmental requirements and activities relating to the development of a multipurpose canister for storing, transporting, and disposing of spent nuclear fuel

from commercial reactors. Argonne also provides technical assistance in the areas of socioeconomic and perceived risk.

Argonne researchers are studying interactions between waste package materials and the unsaturated repository environment associated with the proposed site at Yucca Mountain, Nevada. This work includes elucidating processes that affect the release of radionuclides from high-level waste forms (glass and spent fuel) under simulated repository conditions. Also performed are characterizations of the factors that control the corrosion of metals, to assist in the selection of container material, and studies of the effects of radiation on corrosion and leaching.

The Laboratory is developing a transportation communications system incorporating strong management accountability for hazardous materials shipments and is giving DOE general technical assistance regarding transportation of high-level radioactive materials.

10. General Counsel (UE)

Argonne helps DOE fulfill its responsibilities for environmental analyses of applications to construct and operate facilities to transmit electricity between the United States and neighboring countries. The Laboratory primarily prepares environmental assessments and environmental impact statements describing the effects of construction and operation, in response to requirements of NEPA and other federal statutes governing applications to import electric power and natural gas. The Laboratory recently studied natural gas imports from Canada, exports to Canada and Mexico, demands of specific regions and markets, and cogeneration in regions likely to use natural gas. One product of these studies is a geographic information system for data on natural gas transmission that are relevant for analyzing imports and exports. Future similar projects are expected.

11. Policy, Planning, and Program Evaluation (NA and PE)

In support of environmental policy-making by DOE, Argonne will be analyzing energy and environmental issues. Major future studies will relate to reauthorization and implementation of the Clean Air Act; the Comprehensive Environmental Response, Compensation, and Liability Act; the Resource Conservation and Recovery Act; the Safe Drinking Water Act; the Clean Water Act; and the Endangered Species Act. Other studies will address U.S. Environmental Protection Agency regulations that affect energy development, siting of energy facilities, and policy questions affecting transportation. Argonne provides key support for assessments of atmospheric pollutants, hazardous waste, aquatic effluents, global climatic change, and international trade. Argonne supports the development of models and databases used to assess the environmental implications of U.S. energy plans, policies, and strategies.

Other studies address (1) the impact of federal regulation on exploration for and development of additional domestic petroleum reserves, on shore and off shore; (2) exposure to naturally occurring radioactive materials at oil fields; and (3) benefits associated with using synthetic drilling fluid. Also being analyzed are nonpetroleum transportation fuels, vehicle technology, supplies of fuels, associated infrastructure needed, and the environmental effects of using compressed gas, methanol, ethanol, liquid propane gas, and electricity as transportation fuels. Argonne will continue to examine aspects of utility systems planning as it relates to capacity expansion and import of electricity. Argonne also supports analyses of transportation energy policies and related issues.

Argonne is supporting the U.S. Country Studies Program, which helps developing countries analyze the effects of global climate change. The Laboratory is working on analyses of mitigation strategies. This project builds on earlier work for the Office of International Affairs, in which Argonne developed the ENergy and Power Evaluation Program (ENPEP) computer model, which was designed for wide distribution in developing countries.

The ENPEP system is now being used in more than 60 countries.

12. Economic Impact and Diversity (WA)

Argonne's minority research program helps DOE's Office of Minority Economic Impact comply with the DOE Organization Act of 1977. The program's three broad tasks are (1) to develop and update a database and model describing energy use by minorities, (2) to assess the effects of government energy policies on minorities, and (3) to estimate the effect of key macroeconomic variables on the pattern of U.S. energy demands and expenditures, according to demographic groups.

13. Other DOE Secretarial Offices

In addition to the work for DOE secretarial offices described above, Argonne also conducts generally less extensive work for other secretarial offices, including the Office of Fissile Materials Disposition.

B. Work for Other DOE Contractors

Argonne performs a variety of R&D activities in cooperation with other national laboratories and as a subcontractor to organizations whose primary source of program funds is DOE. This type of work is undertaken when Argonne has technical expertise needed to support major DOE programs being conducted by other contractors.

For several years, Argonne has conducted extensive research on *in situ* bioremediation of a diesel fuel spill at Sandia National Laboratories, Livermore, California. The Laboratory provides technical assistance in the design, implementation, and long-term monitoring of remediation activities. A remediation strategy designed by Argonne was installed at Sandia at pilot scale.

The Laboratory is performing work for Oak Ridge National Laboratory in areas including computed tomography and nuclear magnetic resonance imaging of advanced ceramics and gel-cast composites.

Argonne provides technical support to the Environmental Restoration Program at Los Alamos National Laboratory and to the Rocky Flats Environmental Technology Site in Colorado. This support includes preparation of essential environmental restoration documents, environmental regulatory analyses, and risk assessments.

The Laboratory is providing technical assistance to Pacific Northwest National Laboratory and DOE's Richland Operations Office as a member of the DOE task force supporting activities aimed at potential privatization of the treatment of high-level wastes in tanks at the Hanford Reservation.

C. 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, National Institutes of Health, Environmental Protection Agency, Federal Emergency Management Agency, Department of State, National Science Foundation, Department of Agriculture, Department of Transportation, National Aeronautics and Space Administration, Electric Power Research Institute, Gas Research Institute, private firms, and state and local governments.

Argonne's work for non-DOE sponsors supports accomplishment of its missions (see Chapter II) and development of its initiatives (as described in Chapters IV and V). 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. It 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.

Argonne plans to expand industry sponsorship of its research. For private organizations, the accessibility and attractiveness of the Laboratory's technical resources have improved significantly in recent years because of the more favorable terms under which intellectual property rights can be made available and also because of easier and quicker processing of contracts. The Laboratory will also continue to apply its special capabilities and facilities to research for the Department of Defense.

Areas where Argonne capabilities match the needs of non-DOE sponsors and where the Laboratory plans to strengthen its capabilities in support of DOE missions are neutron irradiation of materials, high-temperature superconductivity, advanced electrochemical technologies, biomedical and environmental research, software for parallel processing, and industrial modeling software.

1. Nuclear Regulatory Commission

Argonne conducts research for the Nuclear Regulatory Commission (NRC) under a legislatively mandated memorandum of understanding between DOE and NRC. The major focus of this research is on materials engineering, thermal hydraulics, and safety analysis. In addition, Argonne provides short-term technical assistance to various NRC offices in many different areas. Both research and technical assistance take advantage of special capabilities that Argonne has developed in areas such as nondestructive testing, numerical simulation, evaluation of fuels and materials, regulatory analysis, and analysis of utility systems.

a. Office of Nuclear Regulatory Research

Most of Argonne's work for the NRC is supported by the Office of Nuclear Regulatory Research. The largest efforts address materials issues, analysis of thermal transients, component reliability, and severe accident behavior.

Materials research focuses on the degradation of structural materials in light-water reactors (LWRs) caused by reactor environments, including the effects of water chemistry and neutron irradiation. These studies include measurements of growth rates of stress corrosion cracks and fatigue life effects in simulated LWR environments on stainless and ferritic steels used in the reactor core, piping, and pressure vessel. Results from these studies will be used by the NRC to ensure the structural integrity of plants as they age. Specimens from operating commercial reactors are analyzed. In addition, extensive irradiation of stainless steels is being performed in Norway's Halden reactor to provide additional systematic data on relationships between material composition and susceptibility to cracking after irradiation.

Argonne has just begun a comprehensive study of degradation in the steam generator tubing of nuclear power plants. This program is intended to support a performance-based integrity rule for the tubing. Critical areas being addressed include (1) evaluation of processes 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 integrity and leakage of degraded steam generator tubes, and (3) validation and improvement of correlations and models for predicting degradation in the tubes as aging occurs. These studies will 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.

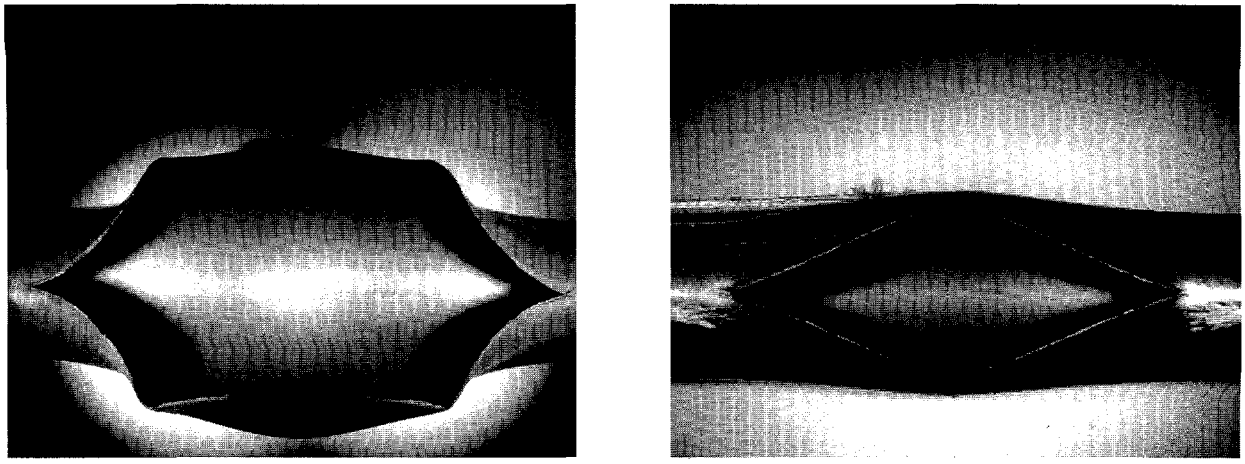


Figure V.14 For the Nuclear Regulatory Commission, Argonne performs tests to determine the behavior of steam generator tubes under severe accident conditions and to investigate how flaws produced by corrosion may decrease the temperature at which tubes fail. The photographs represent catastrophic failure of a tube (left) and failure by formation of a large "fish-mouth" leak (right).

Argonne's thermal hydraulics analysis for the NRC emphasizes detailed analyses of the mechanisms governing postaccident cooling of advanced pressurized-water reactor systems. These analyses include the development of models for liquid-film cooling of containments and comparison of the resulting computer simulations with experimental data provided by vendors. Revisions and modifications of the Argonne COMMIX code, a three-dimensional, general-purpose thermal hydraulics computer code originally developed under NRC sponsorship, are being completed to allow analyses of a variety of thermal transients for advanced configurations of pressurized-water reactors. Emphasis is on postaccident cooling.

Argonne assists the NRC in reviewing the probabilistic risk assessment for the AP-600 advanced-concept pressurized-water reactor design, in the areas of system success criteria and performance reliability of passive-system thermal hydraulics. This work includes (1) identification of parameter uncertainties that significantly affect plant risk, (2) analyses of the sensitivity of system performance to such uncertainties, (3) assessment of margins between predicted system performance and the system-limiting state (the beginning of core damage), and (4) expert judgment and conservative assessments of margins. Internal and external events are considered during both power operation and shutdown. Argonne also advises the NRC on refining, focusing, and redirecting the approach that has been adopted for resolving issues about the reliability of the passive safety system for the AP-600.

The NRC continues to utilize Argonne's broad expertise in reactor safety. A new program is employing laboratory experiments to quantify the energetics of steam explosions resulting from interactions between molten core materials and water. This work focuses on metallic constituents of core melt mass, particularly molten Zircaloy.

Argonne is contributing to understanding the coolability of debris in the Three Mile Island-2 bottom head. Under the auspices of the NRC, the Laboratory is also participating in the provision of technical assistance to Russia through the RASPLAV in-vessel retention experiment program.

Argonne also provides support for NRC's rule making and other regulatory functions by performing regulatory analyses of proposed and final rules and proposed changes to regulatory guides and by analyzing public comments on rule making.

The Laboratory uses simulation models for electric utilities to estimate the cost of replacement energy and other costs when reactors are

shut down. Cost estimates developed for both temporary and permanent shutdowns are updated periodically. These estimates aid regulatory policy-making, particularly regarding temporary shutdowns for safety modifications or permanent shutdowns resulting from severe accidents.

b. Office of Nuclear Reactor Regulation

In addition to experimental research work, Argonne provides assistance to the Office of Nuclear Reactor Regulation on a variety of issues related to the performance of materials. With participation by Brookhaven National Laboratory and Pacific Northwest National Laboratory, this work involves the development of a standard review plan for operating reactors that can be used to assess the suitability of renewing the plants' initial 40-year licenses.

Argonne also provides comprehensive reviews of selected technical literature for the NRC. The reviews focus on issues of materials-related degradation and aging that may be relevant to renewal of nuclear plant licenses. Argonne also provides other support in the general area of managing the aging of nuclear systems.

2. Department of Defense

Argonne is conducting research for several organizations within the Department of Defense (DOD).

a. Office of Secretary of Defense

For the Defense Modeling and Simulation Office, Argonne is developing a sophisticated software architecture for studying the impact of environmental effects on military and civilian operations. Argonne also supports this office in the development of advanced computer architectures for the DOD modeling and simulation community.

b. U.S. Air Force

The U.S. Air Force is sponsoring several programs at Argonne. The Laboratory's experience and expertise in conducting environmental assessments of sites with unique environmental features or 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.

Also for the Air Force, Argonne is developing and demonstrating a number of new technologies and procedures for managing hazardous wastes. Included are bioenvironmental techniques to reduce soil and groundwater contamination at Air Force installations and generally to improve cleanup processes. Systems designed to decontaminate soil in slurry reactors or through land farming are being investigated at sites with several different types of petroleum contamination.

Argonne is also studying a number of environmental systems to identify for the Air Force the most cost-effective technical approaches to environmental management. Included are development of innovative approaches to computer-assisted management of large numbers of air pollutant emission sources in complex industrial areas, development of approaches to risk management, and planning for use of natural resources and land near Air Force installations. Innovative approaches to site characterization and remedial technologies for soil and groundwater contamination are being investigated.

For the Air Force Headquarters Air Weather Service, Argonne is studying the development of an effective theater weather-forecasting capability, focusing on the system's architecture and a general proof of concept. The Laboratory is currently developing a test bed for an appropriate architecture, where the ultimate design goal is short-term forecasts at resolutions as fine as ten kilometers. To effectively

integrate the various component meteorological models needed, Argonne is using its existing Dynamic Environmental Effects Model as the software architecture. The basic forecasting model is a parallel version of a mesoscale model developed by the National Center for Atmospheric Research and Pennsylvania State University. The Laboratory is also using automated differentiation tools to conduct sensitivity analysis of the model. Argonne is performing preliminary model testing by using an advanced scalable parallel processor. In addition, a high-performance network is being implemented at the Global Weather Center located at Offutt Air Force Base.

Argonne is providing technical support for the Air Force's Hypervelocity Rocket Sled Upgrade Program. This work includes technical reviews, advice, and analyses regarding support and guidance systems that use superconducting magnets and cryogenic systems.

c. The Joint Staff

Argonne supports the J-8 Directorate of the Joint Staff. This work entails developing improved planning and simulation models and evaluating advanced information systems to facilitate the use of large databases. An important aspect of the work involves developing innovative uses of rapidly advancing graphics technologies to manipulate and analyze the 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 the earth's surface. The resulting software system, the Dynamic Environmental Effects Model, supports both static and dynamic investigations of geographic areas. It will have wide applicability, both within and outside J-8 and the 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.

Argonne is improving the efficiency of computer models for J-8 in a variety of ways, including their adaptation to advanced processors, and is recommending improved computer system configurations that incorporate advanced multiple-processor computers, high-performance workstations, advanced networking, and greater data storage capacity. In addition, the Laboratory is providing R&D on distributed computing, distributed database management systems, and parallel processing using object-oriented techniques.

Also for J-8, Argonne is pioneering the use of advanced information retrieval techniques in a new planning and decision support system. The system integrates 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.

As part of its work for the Joint Community, Argonne is developing a prototype system for projecting force readiness for the U.S. Forces Command. The system integrates database management technology into a simulation framework to model the processes of force generation and mobilization. This system is proving useful for understanding and planning the initial steps of the force generation process and the time required for mobilization.

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. Infrastructure components are also modeled.

Argonne is deeply involved in the design and implementation of high-performance networks incorporating the latest switching technologies, to give classified suites (both stationary and deployable) and unclassified suites a high level of flexibility and cable management capability. Designs provide for multimedia connectivity worldwide via the Internet and the Defense Simulation Internet. Current efforts in this area are being extended for J-8 and the commanders-in-chief, including the U.S. Central Command and the U.S.-Republic of Korea Combined Forces Command. Long-range plans provide for phased implementation of higher-performance technologies as they evolve.

d. U.S. Army

Argonne is assisting the Army's implementation (in conjunction with the Federal Emergency Management Agency) of the Chemical Stockpile Emergency Preparedness Program. 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 assists in technical management. This work involves hazard analysis, modeling of chemical agent dispersion, development of cost estimation and measurement methodologies, and integration for emergency planning. The Laboratory is also conducting independent reviews of the Army's Phase 1 environmental documents, giving to Congress and the Army comments on the chemical demilitarization environmental process and helping the Army prepare site-specific environmental impact statements.

For the Construction Engineering Research Laboratory of the Army Corps of Engineers, 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 (at Fort Riley, Kansas; Fort Benning, Georgia; and Hohenfels, Germany) that will serve as models for other installations, thereby facilitating integration of training needs with environmental management. These rehabilitation efforts are expanding the baseline for a plant database expert system, which Argonne is developing to help the Army make cost-effective decisions about improving environmental quality at other training areas. Argonne also is creating a knowledge-based air emissions reduction model.

Argonne is also helping the Army Corps of Engineers to implement projects under the Superfund and Defense Environmental Restoration Programs through the Baltimore District. The Laboratory is developing specialized approaches to remedial investigations and feasibility studies, particularly for sites with radiological contamination, and is designing and overseeing implementation of remediation technologies for various sites.

Argonne is conducting an integrated program of environmental and engineering research and technical support for the Army Corps of Engineers (Norfolk District) and the Army's Training and Doctrine Command, examining issues such as land restoration, solid waste management, and cleanup of hazardous waste sites. For the Army Materiel Command, Argonne's expert peer review process is being used to evaluate alternative technologies and regulatory considerations for cleanup activities at the Rocky Mountain Arsenal near Denver, Colorado. Argonne will demonstrate techniques for land reclamation after cleanup at that facility.

Argonne is collecting field samples of military smoke and mathematically modeling its dispersion, in order to estimate health impacts to military and civilian personnel.

Argonne is providing 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 a building decontamination study. Work addresses management of environmental information, special laboratory analysis capabilities, wetlands issues, and containment of groundwater contamination.

Also at the Aberdeen Proving Ground, Argonne is conducting a sitewide environmental assessment that couples advanced database technology to geographic information systems. For the Edgewood Research, Development, and Engineering Center at Aberdeen Proving Ground, Argonne assists in assessments related to environmental compliance.

Argonne is also supporting the U.S. 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 preliminary assessments, site inspections, remedial investigations, feasibility studies, development of master environmental plans for site remediation, application of state-of-the-art environmental data management systems to expedite remedial decision making, and use of groundwater models to evaluate alternative methods of restoring aquifers. The Laboratory is also developing a model plan for decommissioning buildings releasing volatile organic compounds into the environment. Another project for the Army Environmental Center is demonstrating the use of slurry bioreactors for detoxifying soils contaminated with explosives.

For the U.S. Army Defense Ammunition Center and School (USADACS), 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. To assist USADACS in efforts to integrate systems for demilitarization and disposal technologies in the area of large solid rocket motors, Argonne studies relevant individual engineering processes as part of a DOD-wide program.

In a joint effort between DOE and DOD, acting under the Strategic Environmental Research and Development Program, Argonne will help develop a planning methodology for biological conservation and management of natural and cultural resources at installations and sites of the two agencies. The proposed methodology will allow land use conflicts to be identified and optimally resolved and will determine least-cost solutions to long-term land stewardship problems.

e. U.S. Navy

The Laboratory has been applying its rapid, integrated site characterization process, originally developed for hazardous waste sites, in the closure of the Marine Corps Air Station at Tustin, California. The work has been performed for the Naval Facilities Engineering Command, Southwest Division. Argonne's process combines geology, geochemistry, hydrogeology, and geophysics in an integrated hydrogeologic model that is used to guide cleanup decisions. Argonne's innovative work at the large, complex Tustin site now provides the framework for more detailed remedial investigations by private contractors. The

Navy's plan, funding permitting, is to have Argonne design and oversee these future investigations.

f. Defense Nuclear Agency

As part of its arms control program, Argonne is developing verification procedures for the Defense Nuclear Agency. Currently the Laboratory is studying the overall, long-term information and organizational requirements for treaty verification and compliances 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.

The Defense Nuclear Agency's Assistant Directorate for Arms Control and Test Limitations is developing technologies that will be used in the implementation of various arms control treaties. Effective verification of chemical weapons control agreements, such as the recently signed Chemical Weapons Convention, requires protection of the health and safety of inspection teams. To make verification inspections safer, Argonne is demonstrating the feasibility of a sensitive, selective, field-portable air monitor based on electrochemical detection.

g. Advanced Research Projects Agency

For the Advanced Research Projects Agency, Argonne will develop efficient algorithms and software for the symmetric and unsymmetric eigenvalue problem.

3. Other Federal Agencies

a. Environmental Protection

For the Environmental Protection Agency (EPA), Argonne will continue to assess the economic and environmental effects of regulatory initiatives under the Clean Air Act. Emphasis is on issues related to the regulation of fine particulates, ozone, short-term sulfur dioxide standards, and hazardous air pollutants and on implementation of acid rain controls.

To develop algorithms for use in the EPA's next generation of numerical models of atmospheric pollution, Argonne is studying the dry air-surface exchange of nitrogen oxides, sulfur dioxide, submicron particles, and other substances. The Laboratory is also conducting field studies on surface emissions of nitric oxide and, on the basis of field observations and numerical modeling, is developing parameterizations for several atmospheric substances.

Argonne researchers continue to work with the EPA to develop risk models for health effects attributable to human exposure to criteria pollutants. Recently completed were models relating ozone exposures to the formation of lesions in the human lung, decreased lung function, and symptoms such as coughing and chest pain. When necessary, Argonne uses probability encoding to quantify the judgments of health experts about the occurrence of health effects at subclinical exposure levels — levels at which few scientific data exist. These models allow the EPA to evaluate, for example, alternative standards for criteria pollutants in the face of incomplete, but telling, information. Another current project is developing tools to 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, Argonne is identifying and evaluating regulatory prototypes for the petroleum refining industry. Plans call for selected prototypes to be field tested at refineries.

Argonne is providing 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.

The EPA is providing funding for the Pacific Basin Consortium for Hazardous Waste Research, of which Argonne is a member. The Consortium's activities currently include conferences and exchange of information on hazardous waste problems. Cooperative research programs among Consortium members are being planned for funding by the EPA.

To allow EPA Region V to achieve its legislatively mandated obligations for reporting and data dissemination, Argonne will evaluate the existing Superfund database management system and apply its knowledge of Superfund activities and procedures to develop an improved system.

Also for EPA, Argonne is parallelizing weather models to be used in studies of general climate models.

b. Federal Emergency Management Agency

Argonne's support to the Federal Emergency Management Agency involves three major areas relating to 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.

c. Department of State and International Atomic Energy Agency

Since 1976, Argonne has been the host institution for U.S. participation in the training activities of the International Atomic Energy Agency (IAEA). The program emphasizes training in nuclear power, nuclear safety, radiation protection, and energy and environmental planning. In addition to on-site courses, Argonne assists in training programs elsewhere and helps with U.S./IAEA-supported training projects in developing countries.

While development of nuclear power has slowed worldwide, the United States has given increased attention to supporting nuclear safety and applications of nuclear science in fields such as agriculture, medicine, and industry. The International Nuclear Technology Liaison Office was set up by the Department of State to coordinate U.S. participation in the IAEA, especially in the sphere of technical cooperation, and Argonne acts as its operating agent.

Argonne is presenting training courses for the IAEA in selected topics in nuclear science and technology. A course on radiation protection was presented for the first time in 1994. A course on applications of nuclear analytical techniques to air pollution has been held periodically. These offerings complement courses on energy and environmental planning and on nuclear and radiological safety. The Laboratory anticipates that international training courses on safe operation of nuclear power plants and on energy and environmental planning for developing countries will occupy 25-28 weeks each year.

The IAEA has supported Argonne's development of planning tools for studies to support decision making on energy and the environment. These tools are distributed to the ministries of energy and electric utilities in IAEA member states.

Each year Argonne participates in several IAEA missions to provide technical assistance and training to energy and environmental planners in selected IAEA member countries. The missions generally involve training and applications using one or more component models of a planning system developed at Argonne.

d. Agency for International Development

Argonne participates in the Soviet-Designed Reactor Safety Program, helping DOE to manage, plan, and carry out projects to improve the safety of Soviet-designed nuclear power

plants and to improve the safety culture of countries operating those plants. This work is partially funded by the Agency for International Development and managed by DOE. Argonne safety experts were instrumental in developing the near-term risk reduction measures organized under the Lisbon Nuclear Safety Initiative, which aimed to reduce the risks of operating older Soviet-designed plants in Russia and Ukraine. Currently, the Laboratory is providing lead technical support for plant safety evaluation within the Soviet-Designed Reactor Safety Program.

e. Health and Human Services

The National Institutes of Health (NIH) support a broad range of fundamental studies at Argonne. These investigations generally apply techniques developed in DOE-supported programs to fundamental studies in biophysics, carcinogenesis, mutagenesis, physiology, and radiation research.

The majority of these studies emphasize structure-function relationships or mechanisms underlying biological responses. The effects of chemopreventive agents, radiation quality, dose, and dose rate are being assessed by using *in vitro* cell cycle studies and *in vivo* mutation assays to modify, predict, and quantify chemopreventive effectiveness and carcinogenic potential. One study focuses on the identification and characterization of genes that are induced in cultured cells following exposure to 60-hertz electromagnetic fields. The objective is to determine mechanisms for specific gene induction.

Biophysical studies are determining, at atomic resolution, the structures of bacterial photosynthetic reaction centers; also being addressed are the biophysical properties of human antibody light chains that lead to pathologic deposition in myeloma. Investigations of *in vitro* aggregation of human antibody light chains will consider their structure and pathologic characteristics. One study is investigating the role of metallothionein in the metabolism and toxicity of heavy metals such as cadmium.

The NIH has funded Argonne to develop area detector technology for protein crystallography. The specific aim of this collaborative project with Brandeis University and Radiation Monitoring Devices is to develop area-sensitive electronic X-ray detectors employing amorphous silicon arrays to record diffraction data for protein crystallography. (This technology is based on the design of a charge-coupled device developed under funding from DOE's Office of Health and Environmental Research.)

f. Department of Transportation

For the Research and Special Projects Administration of the Department of Transportation and in conjunction with the Federal Emergency Management Agency, Argonne continues to support two interconnected nationwide electronic bulletin boards with 30,000 registered users. The purpose of the bulletin boards is to disseminate information on hazardous materials that is needed for emergency planning. Argonne is also preparing emergency planning and response guidance documents, developing and using related computer modeling systems, and creating and maintaining related computer information systems for hazardous materials transportation emergencies.

g. Department of Agriculture

As part of an ongoing program for the U.S. Department of Agriculture (USDA), Argonne is supporting 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 USDA's remediation requirements. Argonne has already successfully developed and applied (1) new methods to prioritize sites for study and treatment, (2) innovative technologies for rapidly remediating contaminated water supplies, and (3) nonintrusive characterization

methods to minimize subsurface drilling and sampling in populated areas.

h. National Science Foundation

Between 1989 and 1992, the National Science Foundation (NSF) sponsored an R&D program on seismic isolation, which was carried out jointly by Argonne and the Shimizu Corporation of Japan. Extensive data on the response of seismic isolation systems to actual earthquakes were recorded and analyzed. Two different types of elastomeric seismic isolation bearings were installed in a full-size test facility in Sendai, Japan. Though the formal program has ended, data are still being collected by Shimizu and routinely furnished to Argonne for analyses.

Argonne is a member of an NSF-sponsored Science and Technology Center for High Temperature Superconductivity with the University of Illinois at Urbana-Champaign, Northwestern University, and the University of Chicago. The Center is described further in Section V.C.4.e.

Argonne is the lead laboratory for teacher training supported by NSF, which is conducted at ten DOE national laboratories and involves teachers at the elementary and junior high levels. Teachers interact with scientists in their work environment and experience the research process firsthand, enhancing their understanding of science and their science teaching.

With Rice University, the California Institute of Technology, Syracuse University, the University of Tennessee, the University of Texas, and Los Alamos National Laboratory, Argonne participates as a partner in the NSF-sponsored Science and Technology Center for Research on Parallel Computation. This Center is described further in Section V.A.2.l.

i. National Aeronautics and Space Administration

For the National Aeronautics and Space Administration, Argonne is investigating the use of automated differentiation techniques to provide reliable, fast derivatives for large-scale FORTRAN programs.

4. Nonfederal Organizations

a. Electric Power Research

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 are now being analyzed. Argonne's current work on the Melt Attack and Coolability Experiment program is particularly timely. It investigates the ability of water to quench and cool a pool of molten core debris without formation of an insulating crust, thereby terminating an accident and preventing basemat penetration. This 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 part of 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. EPRI is attempting to close unresolved issues with the U.S. Nuclear Regulatory Commission. The Laboratory's contributions are a key part of the work needed to meet that objective.

b. Gas Research Institute

Under funding from the Gas Research Institute, Argonne is collaborating with the U.S. Geological Survey, the U.S. Army Corps of Engineers (New Orleans District), and DOE in a major multiyear field project to examine the causes of wetland loss in the Louisiana Deltaic Plain. In another study, Argonne is investigating the concept of mitigation banking as an alternative to the principle of "no net loss" of wetlands in areas of energy development and transport. Cooperating organizations, in addition to the Gas Research Institute, are the American Petroleum Institute, DOE, and the Interstate Natural Gas Association of America.

c. Private Firms

Argonne is conducting research for a number of private firms, making use of its special facilities and technical resources. These firms include AlliedSignal Aerospace, BDM International, Caterpillar, Chicago Manufacturing Center, Commonwealth Edison, Decision Focus, Genencor, General Motors, International Fuel Cells, M-C Power, 3M, Pacific International, Rust Engineering, and Solar Turbines.

Argonne is working with the Electro-Motive Division of General Motors, focusing on development of the company's new "H" engine. Of particular interest are the Laboratory's broad capabilities in areas such as friction and wear technologies, advanced materials, and emission control methods. A one-cylinder version of the prototype engine is to be relocated to Argonne shortly, and a 16-cylinder version may be moved to the Laboratory later.

Argonne's work for private firms often grows out of industry-laboratory collaborative projects (see Section VI.A.1). A good example of a new Argonne facility growing in this direction is the Laser Applications Laboratory, which conducts R&D to support the use of high-power lasers in materials processing for manufacturing. Current work supports a number of CRADAs funded by the Energy Research-Laboratory Technology Research (ER-LTR) Program. (See Section V.A.2.o.) Industrial partners include the U.S. textile industry through the AMTEX partnership, the Low Emissions Partnership of the U.S. Council on Automotive Research, Spawr Industries, Laser Mechanisms, Caterpillar, and U.S. Laser. Processes being pursued include high-power beam shaping and delivery, fiber optics, cladding, heat treating, and welding. The Laser Applications Laboratory also does work in support of Argonne's major facilities and programs, such as the Advanced Photon Source, the Intense Pulsed Neutron Source, and the Fusion Power Program.

Argonne's extensive collaborative research with the private sector is described in Section VI.A.

d. State of Illinois

At Argonne's Advanced Photon Source, the state of Illinois is supporting the design and construction of a user residence facility for visiting scientists and students. (See Section V.A.2.g.)

e. University of Illinois

Argonne is a major participant in an NSF-sponsored Science and Technology Center for High Temperature Superconductivity, with the University of Illinois at Urbana-Champaign, Northwestern University, and the University of Chicago. Research at the Center focuses on theory, synthesis and structure, bulk properties, and vortex phenomena. All of these areas of research are important to Argonne's work for DOE, which the Center complements extremely well. In the Center's educational activities, Laboratory personnel play key roles in all areas, particularly precollege and minority education. Argonne personnel also play key roles in linking the Center's basic research program to the needs of U.S. industry.

f. World Bank

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, and simulating the operation of mixed hydrothermal systems. Argonne typically conducts these studies in close cooperation with system planners in the borrowing counties, who are often trained to use the analytical techniques themselves.

g. North Atlantic Treaty Organization

For the Science Committee of the North Atlantic Treaty Organization, Argonne organized a workshop on problems associated with decommissioning the Russian nuclear submarine fleet. The workshop was held in Moscow in June 1995.

h. Foreign Countries

Argonne scientists pioneered in developing the technology for niobium superconducting radio-frequency accelerating structures (resonators) used in heavy-ion nuclear accelerators. The Laboratory recently furnished resonators to the University of Sao Paulo in Brazil and is training members of the University's research staff in superconducting linac technology by involving them in R&D at ATLAS. In addition, the Laboratory is developing a new prototype cryogenic resonator for the Nuclear Science Centre in New Delhi, India. Argonne will fabricate the first group of accelerating structures by following that design.

In work for the Korea Institute of Energy and Resources, Argonne is using numerical atmospheric models to simulate short-range transport and diffusion over mesoscale distances. The objective is improved understanding of relationships between plume paths and air quality problems in the Seoul area.

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). Laboratory staff recently assisted Uruguay's Presidential Office of Planning and Budget in formulating national energy policy. Being negotiated is a project to provide technical assistance and energy and environmental analyses to the Turkish Electricity Generation-Transmission Corporation and the Turkish Ministry of Energy and Natural Resources.

D. Laboratory Directed R&D Program

Laboratory Directed R&D (LDRD) is an Argonne program that funds innovative R&D projects that are not eligible for timely support through existing programs. Selection is the responsibility of the laboratory director. The basic objectives of the LDRD program are to maintain the scientific and technological vitality of the Laboratory and to respond to rapidly emerging R&D opportunities more quickly and effectively than would otherwise be possible. Ultimately, the objective is to enhance Argonne's ability to pursue its missions for DOE.

All LDRD projects, whether chosen centrally or by decentralized delegation from the laboratory director, are explicitly selected according to the same criteria. Among the selection criteria, the most basic is scientific and technical excellence. Others are relatedness to Laboratory strategic goals and objectives, innovativeness, expected contributions from the results, and prospects for future support. In addition, each year the laboratory director designates portions of the LDRD budget to emphasize particular types of projects. Currently so designated are (1) projects linking basic research to applied research and (2) small, short-term, single-investigator projects.

Though the LDRD program is relatively small in terms of funding, it serves vital roles: (1) supporting the Laboratory's mission and strategic initiatives, as described in this document; (2) enriching the Laboratory's technical capabilities; (3) encouraging innovation by the technical staff; (4) reinforcing the Laboratory's R&D planning; and (5) exploiting

the technical potential of the Laboratory for the benefit of the nation. A typical immediate aim is to investigate new ideas to the point of "proof of concept," to give potential sponsors of future programs concrete information on which to base their evaluations. In addition, the program has the very important benefit of enhancing the morale and vitality of the Laboratory's scientific staff. Researchers' enthusiasm is nurtured by the knowledge that good new ideas, even if they appear tangential to existing programs, will be eligible for the immediate funding they need.

Argonne's LDRD program supports promising novel and innovative projects wherever they may arise in the context of the full range of Laboratory missions. Several areas receive particular emphasis, both because they coincide naturally with the existing spectrum of technical expertise of Laboratory staff and because successful outcomes of projects in these areas can most readily be translated into a strengthening of current DOE programs and development of new programs. Current areas of emphasis are the following:

- Advanced accelerator and detector technology
- X-ray techniques for research in the biological and physical sciences
- Nuclear technology
- Materials science and technology
- Computational science and technology
- Biological sciences
- Environmental science
- Environmental control and waste management technology

By their very nature, recent successes from Argonne's LDRD program have only begun to yield scientific and technical payoffs, and their ultimate benefits to society will not be known for many years. During FY 1995, LDRD funding supported a variety of research accomplishments, including the following:

- Researchers in Argonne's Computing and Communications Infrastructure Futures Laboratory successfully demonstrated a prototype video server that provides the first integrated environment for network-based collaborative research. Features include hypermedia indexing and multimedia recording and playback. This effort has already led to a spin-off project funded by DOE, to develop a "Video Voyager" for handling media stream data on scalable hardware like the IBM SP.

- Progress was made toward developing an innovative method for analyzing hyperdimensional, multispectral, remotely sensed data for environmental remediation applications. The objective is a new way of examining and defining specific trends in a hyperdimensional spectral space to characterize locally distinct environmental features at selected spectra.

- To study the properties of clusters of transition metal atoms by using a brilliant X-ray source such as the APS, continuous high-fluence beams of the clusters are needed. These aggregates of many tens of atoms have interesting fundamental properties differing from both those of single atoms and molecules and those of the corresponding solid. Argonne researchers have now demonstrated high-intensity quasi-continuous cluster beams of iron, nickel, rhodium, and platinum by using (1) high-repetition-rate, pulsed, high-power lasers directed at metal targets for vaporization and (2) a flowing inert-gas environment to promote condensation into clusters.

- The feasibility of a qualitatively new architecture for large-area silicon array detectors for ultraviolet and X-ray radiation was demonstrated. Two distinct technologies — large-area arrays of amorphous silicon photodiodes and thin-film semiconducting scintillators (e.g., made of lead iodide) — were successfully coupled and matched with electronic readout devices. The feasibility of the hybrid device for

crystallographic and other applications at synchrotron light sources was shown.

- A unique computational method was devised to calculate the properties and chemical reactions of large biological systems containing thousands of atoms, such as enzymes. The method combines quantum mechanical and molecular modeling schemes and employs fast, semiempirical computational methods on massively parallel computer architectures. Techniques of this power and capacity will allow data gathered from X-ray scattering and diffraction experiments at Argonne's Structural Biology Center to be related to the fundamental structures of the systems studied, possibly even for time-dependent phenomena.

- Two novel approaches were demonstrated for using heavy-ion irradiation damage to introduce columnar flux pinning centers into high-temperature ceramic superconductors. The resulting defects effectively pin magnetic flux lines (vortices) in the vortex liquid state of these systems. In one approach, heavy-ion tracks were "splayed" at various angles to increase the effectiveness of the vortex pinning. In the second approach, a slit narrower than one micrometer restricted the columnar defects to specific channels, with the resulting artificial geometry allowing measurement of vortex flow viscosity.

In FY 1995, several LDRD projects continued under the auspices of Argonne's Coordination Council for Science and Technology, which comprises division directors from across the Laboratory. In addition to satisfying all other LDRD requirements, projects recommended through the Council must explicitly mate basic and applied research. The objective is to generate results that are closer to applications than would otherwise be the case.

The LDRD program is funded Laboratory-wide through the Laboratory's indirect budget. More than 90% of the projects are selected centrally by the laboratory director in close consultation with other members of the Laboratory's Strategic Planning Board. The rest are selected by associate laboratory directors, subject to final approval of LDRD proposals and spending plans by the laboratory director. A combined report of the accomplishments of the entire LDRD program is made to DOE each year.

As part of its LDRD planning before each fiscal year begins, Argonne proposes to DOE a maximum LDRD expenditure. As indicated in Table V.11, for FY 1996-FY 1998 this upper limit approximates 3.5% of projected total operating funds for the Laboratory. Actual expenditures on LDRD projects typically fall somewhat short of this planned maximum (as in FY 1995), depending on the nature of the LDRD projects that are ultimately proposed and selected.

Table V.11 Laboratory Directed R&D Funding
($ in millions)

FY95[a]	FY96[b]	FY97[c]	FY98[c]
13.6	17.5	16.7	17.8

[a]Actual expenditures.

[b]Authorized maximum expenditures for the LDRD program.

[c]Planned maximum expenditures for the LDRD program.

VI. Technology Transfer and Science and Math Education

In pursuit of its R&D and technology transfer missions, Argonne interacts extensively with academic and industrial researchers, with companies interested in using the Laboratory's new technologies, and with science educators and students. Interactions with industrial firms — in many cases R&D partnerships — enhance the Laboratory's programs, while ensuring that research findings and methods developed at the Laboratory can be exploited commercially. The Laboratory's educational programs promote interest in science and technology among students and encourage scientific learning while bringing the talents of enthusiastic academic researchers to bear on Argonne's research programs. The Laboratory's national user facilities provide unique capabilities to scientists from universities and industrial firms spanning the nation. This section describes the extent and the importance of these interactions between Argonne and organizations and individuals outside the federal government.

A. Technology Transfer

Argonne's Industrial Technology Development Center is an organizational mechanism dedicated to achieving effective technology transfer and industrial collaboration. Reporting to the general manager for energy and industrial technologies, the center manages industry-laboratory 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 Laboratory technology.

The Laboratory's director leads technology transfer, particularly by defining relevant Laboratory policies. An advisory committee of Argonne's Board of Governors provides guidance. Technical staff in the Laboratory's research divisions generate new technology and work toward its transfer to industry.

As described in the strategic plan for Argonne's R&D programs in energy and industrial technologies (Section III.D.3.a), industrial partnerships are a pervasive mechanism that Argonne employs to maximize the commercial applications and benefits to the nation resulting from its R&D. Managers from relevant Laboratory programs meet weekly as the Industrial Partnerships Committee, to strategically explore opportunities for technology transfer to industry and for R&D programs that will lead to such transfers. In addition, four subcommittees meet regularly to coordinate opportunities in focus areas based on the Laboratory's research: (1) materials development, (2) manufacturing technology, (3) transportation technology, and (4) energy and environmental technology.

Despite recent funding cuts, Argonne plans to continue its aggressive pursuit of technology transfer. Table VI.1 summarizes the funding and staffing associated with these plans.

1. Research and Development Agreements

Collaborative research at Argonne is generally conducted under CRADAs and HTSCAs. Other types of agreements employed include personnel exchanges, work for others, and technical services program agreements.

Table VI.1 Technology Transfer Funding and Effort[a]

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Funding ($1,000)							
ORTA/Industrial Technology Development Center[b]	2,156	2,400	2,550	2,650	2,750	2,850	2,950
ER-LTR[c]	2,787	6,000	7,000	9,000	10,000	11,000	11,500
Non-ER-LTR[d]	20,000	22,000	25,000	30,000	35,000	40,000	45,000
High Temperature Superconductivity Technology Center	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Total Federal Cooperative Research Funding	25,787	31,000	35,000	42,000	48,000	54,000	59,000
Total Industry Funding	40,000	50,000	55,000	60,000	65,000	70,000	75,000
Staffing (FTE)							
ORTA/Industrial Technology Development Center Activity	9	9	9	9	9	9	9
Patent/Licensing Activity	5	5	5	5	5	5	5
CRADA/HTSCA Activity	197	202	221	272	296	317	340
Total Staffing	211	216	235	286	310	331	354

[a]Projections reflect estimates of available federal funding. For cooperative research activities, these projections are significantly below the corresponding level of demonstrated private demand.

[b]Includes funding for outside patent attorney services, at $225,000 annually, escalated for inflation.

[c]The Energy Research-Laboratory Technology Research Program.

[d]Funding for CRADA projects from non-ER-LTR programs. This funding is included with the resources for the relevant DOE programs in Chapters V and XII.

a. 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 gained access to industrial expertise and facilities that are not available on-site. Cooperative research has also 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 vehicles, such as technical conferences, trade shows, direct mailings, announcements in *Commerce Business Daily*, and articles in trade journals and other publications.

By January 31, 1996, the Laboratory had executed 146 CRADA actions, 40% with small businesses. Of these, 115 were new CRADAs, and 31 were amendments to existing agreements. The total contract value was approximately $124 million, with government and industry contributions roughly equal. However, industry provided $19 million in funding directly to Argonne to support the Laboratory's efforts under CRADAs. These investments give strong evidence of the value that industry places on partnerships with Argonne. The remainder of this section is devoted to highlighting some of the Laboratory's significant industrial partnerships.

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 these CRADAs — with Amoco Oil Company, Phillips Petroleum Company, Chevron Research and Technology Company, and UOP, Inc. — is using state-of-the-art laser optics instrumentation to test commercial fluid catalytic cracking unit feed nozzles. Test data from this unique collaboration will allow the development of more efficient nozzles.

In other CRADA work with Amoco, Argonne is continuing its development of technology for producing syngas by using ceramic membranes. This project may expand to a multimillion-dollar demonstration project including other industrial participants. Argonne also is working with Shell Development Company to examine methodologies for mitigating fouling of refinery heat exchangers. A CRADA with Chevron Research and Technology Company is expected to define a process for efficiently identifying corrosion-producing acids in vacuum gas oils and crude oils, which will facilitate the development of treatment processes.

A large project with Illinois-based NTEC EDSep, Inc., aims at developing advanced electrodialysis technology for preventing pollution in the process industries. A CRADA with Applied Natural Sciences, Inc., is developing phytoremediation technology using green and woody plants to clean up DOE and other waste sites.

Argonne has several continuing projects with the transportation industry that also focus on reducing energy use and minimizing environmental impacts. Contracts with the U.S. Council for Automotive Research (USCAR, a partnership with the Big Three automakers) focus on pollution control, laser beam welding, and development of advanced batteries for electric vehicles. Also under the USCAR umbrella, a continuing CRADA with 3M and HydroQuebec aims to develop lithium-polymer batteries for electric vehicles. A new CRADA with a consortium of laser technology companies focuses on the development of advanced laser welding technology for application in the automotive industry. A CRADA with the American Association of Railroads (the trade association for the North American railroad industry) focuses on improving combustion and pollution control technology.

Argonne continues its involvement in the U.S. textile industry partnership AMTEX through two CRADAs addressing computer-aided fabric evaluation and textile resource conservation. The Laboratory has a representative on the AMTEX advisory board and is leading the organization's waste management effort.

Of Argonne's CRADAs, 63% have been supported by DOE's Energy Research-Laboratory Technology Research (ER-LTR) Program. Many of these CRADAs have had significant impacts on the participating industrial partners and, in some cases, on entire industries. For example, Southern California Gas Company (SoCalGas) has reduced its annual operating costs by an estimated $1 million through joint research with Argonne on microbally influenced corrosion; several

other companies have indicated an interest in joining a consortium coordinated with this CRADA, which is being formed by SoCalGas.

Argonne CRADAs also involve foreign partners, as directed by the Nunn-Luger Act. Under that legislation, the United States is helping countries of the former Soviet Union divert the staff of their weapons institutes to nonmilitary activities. The Newly Independent States Industrial Partnership Program (NIS-IPP) and the U.S. Industry Coalition (USIC) were developed to facilitate cost-shared commercialization projects that further those objectives. In 1995 Argonne executed three CRADAs with USIC members and played a significant role in the development of the intellectual property agreements now used throughout the NIS-IPP. Argonne executed CRADAs with U.S. Bioscience for the evaluation of radioprotectors; with SI Diamond Technology, Inc., for the development of nanocrystalline diamond thin-film cathodes for field emission displays; and with Phase Metrics for the development of flux imaging systems for analyzing superconducting materials.

b. High Temperature Superconductivity Technology Center Agreements

Under a typical HTSCA, both the partnering organization and Argonne contribute to the cost of the research. Proprietary information is kept confidential, and the results of the work can be protected from disclosure for up to two years. A company may obtain rights to intellectual property developed under the agreement.

By January 31, 1996, Argonne had executed 72 HTSCAs — 42 new agreements and 30 amendments. The total value of contract contributions from Argonne and industry was $26 million. Of this amount, 22% was provided directly to the Laboratory by industry partners. The firms involved range in size from Fortune 500 companies to start-up companies with only a few employees. Industrial interest remains high, and many firms are renewing previous contracts.

Under HTSCAs, Argonne has developed several enabling technologies that are now being used by industry, including vacuum calcination for powder synthesis, microstructural texturing, silver composite processing, and melt processing. In addition, the Laboratory has developed four product-oriented technologies: a cryogenic fluid level sensor, current leads, magnetically levitated bearings, and superconducting wires.

Argonne's strength in advanced materials development 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 has been particularly valuable to small companies that were formed to pursue commercial applications of high-temperature superconductivity. One such company, Superconductive Components, now manufactures four varieties of high-temperature superconducting powders by using an Argonne process that won an *R&D* 100 Award in 1994. Compared with alternatives, this method reduces processing time by 60% and yields cost savings estimated at 40% (about $180 per pound of material produced).

Intermagnetics General Corporation and Argonne worked together to meet the challenge of producing ceramic superconductors in the form of long wires and tape suitable for practical applications. An HTSCA led to the fabrication of a magnet containing approximately 480 meters (1,500 feet) of flexible superconducting tape, which produced a record-breaking magnetic field of 2.6 tesla. Work with Argonne on next-generation superconductors has positioned Intermagnetics General to expand its product line to high-temperature superconductors. The company has already manufactured prototype high-temperature superconductor products that are close to commercialization.

c. Personnel Exchanges

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 perspectives, and mutual familiarity

and understanding often lead to subsequent collaborations.

Argonne exchanges scientific staff with industrial firms through a variety of mechanisms, including CRADAs and guest agreements. Appointments typically range from three months to one year, though they may be as brief as a few days.

d. Work for Others

Argonne may conduct work for sponsors other than DOE, including industrial firms, universities, and state and local governments. This "work for others" is discussed in Section V.C.

e. Technical Services Program Agreements

Argonne provides technical assistance to companies through its Technical Services Program, which is supported by the ER-LTR Program. These agreements allow Argonne scientists with unique expertise to provide limited scientific assistance, typically to help small businesses solve immediate technical problems. Since the program's inception in FY 1994, the Laboratory has assisted 60 companies in this way. In some cases, a CRADA or other wider ranging collaboration has resulted.

2. Patent and Software Licensing

In FY 1992, the University of Chicago began using federal funds to patent inventions and to register copyrights for software. This intellectual property is primarily used to support CRADAs, HTSCAs, and other cost-shared collaborations. Acquisition of intellectual property developed under programs that are not directed toward cost-shared collaborations is generally pursued with private funding by the ARCH Development Corporation, an affiliate of the University of Chicago.

The acquisition and protection of Argonne intellectual property have been pursued aggressively under both types of funding. By February 1996 ARCH and Argonne had taken title to a total of 273 inventions. Patent applications had been filed on 213 of these inventions and patents issued for 101. Where appropriate, filings under the Patent Cooperation Treaty were made to preserve foreign patent rights for licensees.

Argonne also has continued its drive to identify and transfer software of value to others. Nearly 50 software codes have been reported, with 41 requests for permission to assert copyright submitted and approved by DOE. Copyright registration is pursued both for codes intended to be transferred to industry and for codes to be broadly provided under free licenses.

To manage more effectively decisions as to whether an invention should be acquired under federal or private funding, the Laboratory and ARCH cooperatively developed a categorization system. In this system, inventions arising out of field work proposals are categorized as "Series 100" if the work may be directed toward, or involves, cost-shared agreements between Argonne and industry. Other inventions are categorized as "Series 200." The Laboratory's Industrial Technology Development Center has the first option to acquire Series 100 inventions under federal funding. ARCH has the first option to acquire Series 200 inventions under private funding.

Laboratory inventions and software are protected with federal funding to prepare for potential licensing to existing industrial partners and to establish technical leadership in areas in which the Laboratory is interested in forming industrial collaborations. Detailed procedures for electing, patenting, cost-tracking, and licensing inventions under federal funding have been developed and implemented. Relational databases are used to coordinate intellectual property acquisitions and licensing arrangements with collaborative agreements that have been executed or are in process.

The number of licenses, license options, and assignments executed by Argonne under federal funding has been increasing steadily, from one in FY 1992 to ten in FY 1995. (These numbers

include only licenses and options relating to specific, identified intellectual property; in contrast, CRADAs generally include an option to acquire whatever intellectual property may be generated under the agreement.) Initial fees and running royalties associated with executed licenses vary from no-cost licenses up to potential payments of millions of dollars. To encourage cost-shared partnerships, the negotiated terms of licenses are generally very favorable to industrial partners. In addition to licenses granted to industry, a few software program copyrights are distributed publicly under no-cost licenses.

The ARCH Development Corporation continues to pursue the commercialization of Argonne inventions through private funding. Since FY 1987, ARCH has executed 39 licenses and license options and created four new companies based on Argonne inventions. One start-up company, Eichrom Industries, continues to generate significant royalties from its sale of products. Stock for another of these companies, Illinois Superconductor Corporation, went on public sale in FY 1994. Table VI.2 indicates that returns from the sale of ARCH's stock in this company have been significant.

Reporting and transfer of computer software by Argonne have been increasingly successful. Through January 1996, nearly 70 software codes had been formally reported; DOE approved the Laboratory's requests to assert copyright to more than 40 of these. A total of 28 software copyrights have been licensed under 15 agreements. Fifteen codes are now generating earned royalties. Publication copyrights are being increasingly emphasized. With DOE permission, the Laboratory asserted copyright to ten publications; eight were licensed to a distribution house for the *New Explorers* videotapes and guides. Trademarks associated with copyrights are registered where appropriate and licensed with the copyrights.

Argonne has developed a comprehensive set of policies and procedures for copyrights and software to satisfy DOE orders and meet the full range of the Laboratory's administrative concerns.

Table VI.2 Licensing Income and Use

	FY95	FY96	FY97	FY98	FY99
Licenses[a]					
Number of New Licenses					
ARCH	1	6	6	6	6
Argonne	10	12	12	12	12
License Income[b] ($1,000)					
ARCH	777	1,650	150	150	150
Argonne	107	200	200	200	200
Total	884	1,850	350	350	350
Use of Income ($1,000)					
ARCH Administration[c]	583	1,238	112	112	112
ORTA Administration	0	0	0	0	0
Laboratory R&D[d]	80	150	150	150	150
Awards and Inventor Payments[e]	221	462	88	88	88
Total	884	1,850	350	350	350

[a]Includes licensing, options to license, and assignments to industry.

[b]Includes $467,000 in FY 1995 and $1,500,000 in FY 1996 from the public sale of stock in an ARCH start-up company.

[c]Equals 75% of ARCH royalties.

[d]Equals 75% of Argonne royalties.

[e]Equals 25% of total royalties.

To support existing partners in cost-shared agreements and encourage new agreements, Argonne has developed procedures to ensure that intellectual property is adequately protected and that industrial partners are informed of inventions and software developed under their cost-shared agreements or otherwise related to their R&D areas.

Work performed by Argonne and its partners under cost-shared agreements such as CRADAs and HTSCAs — sometimes at the cutting edge of technology — has been very productive. Through January 1996, 52 inventions had been reported as conceived under these agreements. Industrial interest in these inventions runs high; by early 1996,

licenses for 20 of the inventions had been arranged or were being seriously negotiated.

Table VI.2 describes the amounts and uses of income from the licensing of Argonne inventions. Royalties received to date stem from three sources: up-front payments for licenses and options, running royalties from the sale of products, and the sale of stock by ARCH.

Royalties from federally funded commercialization began in FY 1994. Royalties remaining after shares are disbursed to inventors and authors will be used by Argonne to support the further development of intellectual property and its transfer to private industry. Through January 1996, the Laboratory's share of these royalties was used to initiate selected work-for-others projects that otherwise required overly burdensome up-front payments from small businesses. When the Laboratory completes its work under such an arrangement and the small business sponsor pays, the Laboratory's royalty account is to be replenished.

3. Outreach and Business Development

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 directly and through state and local economic development organizations. Argonne's Industrial Technology Development Center coordinates outreach activities and serves as the central point of contact for companies wishing to explore Laboratory capabilities and industry partnerships. Program development and communications functions within the Laboratory are closely coordinated. Attention focuses on four major industrial areas: materials, manufacturing, transportation, and energy and environmental technology.

One major channel of communication is publication of articles in scientific and technical journals. In addition, Argonne publishes a quarterly newsletter, *Tech Transfer Highlights*, targeted to industrial firms. Circulation is roughly 4,500. Participation in trade shows often involves formal Argonne exhibits. In FY 1996, projected total attendance at major trade shows in which the Laboratory is scheduled to participate is approximately 200,000. Standard public relations techniques such as press releases are employed extensively.

Each year, the Center responds to approximately 2,500 inquiries from industry. The Center 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 organization, program, or service outside the Laboratory.

Awards for technology transfer, such as those presented by the Federal Laboratory Consortium (FLC), highlight some of Argonne's successful partnerships with industry. The Laboratory won its 15th FLC award in 1995, for successfully transferring to industry a technique for processing superconducting powders that had earlier won an *R&D* 100 Award. The powders are already commercially available. In 1995, the Laboratory won an *R&D* 100 Award for transferring technology for upgrading natural gas into pollution-reducing fuel additives, liquid fuels, and other valuable chemicals.

B. Support of Science and Math Education

Argonne's interactions with the academic community are multifaceted and extensive. These interactions range from activities that are primarily educational to graduate-level research collaborations having a significant educational component. The Laboratory directly provides programs of many kinds to nearly 4,000 teachers, students, and researchers from about 270 institutions throughout the nation. Outreach activities such as tours and electronic communication systems reach thousands of others. All programs strongly emphasize participation by women and underrepresented minorities.

Argonne's faculty programs aim to support faculty development in research and teaching

and to communicate current research results and new discoveries to faculty. Major activities include summer research appointments (Faculty Research Participation), sabbatical year research appointments (Faculty Research Leave Appointments), and faculty conferences and workshops.

Argonne's graduate programs aim to support graduate student research in areas of interest to DOE and Argonne and to develop new generations of well-trained scientists doing research in these areas.

Argonne's undergraduate research participation programs give students substantial experience as part of a research team. The Summer Research Participation Program provides about 200 appointments each year. The Science and Engineering Research Semester is offered during the academic year. These programs are supplemented by seminars, tours, and academic courses. The Laboratory also holds special events such as the annual Graduate School Fair in Science and Engineering and the Argonne Undergraduate Research Symposium.

The Chicago Science Explorers is a major science education program combining the stimulation of outstanding television programs produced by television journalist Bill Kurtis with the resources of many of the major Chicago organizations engaged in science and science education. This program has supported teachers, supplemented classroom activities, and annually through 1995 provided hands-on activities at various sites outside the classroom for over 100,000 students in the city of Chicago, along with their teachers. With the generosity of Mr. Kurtis and support from DOE, tapes of the shows, along with supplementary materials and information about supporting activities organized by Argonne for the Chicago program, were made available to teachers throughout the country. Other organizations, including several DOE laboratories, organized support programs in other parts of the country. This successful program will reach its objectives by the close of FY 1996.

Argonne's National Instrumentation Sharing Program makes available a variety of experimental resources for educational experiments at both the college and precollege levels. These activities are centered at a well-equipped teaching and research laboratory.

1. Laboratory Education Support Plan

Table VI.3 characterizes Argonne's existing educational programs. The total number of appointments and the numbers of minorities and women are shown for FY 1994 and FY 1995. Demand for programs at Argonne remains very strong.

Argonne comprehensively supports science education at all educational levels. The Laboratory's strategic plan for educational activities is refined frequently to reflect new opportunities and priorities.

Programs for science teachers are designed to end their typical isolation in the school and to give them opportunities to work in a stimulating scientific environment. Teachers in the Chicago public schools are given refresher programs in their disciplines and information about recent scientific developments. Contact with other science teachers and with Argonne staff is important and is maintained through a growing, active teacher network, called the Argonne Community of Teachers.

Undergraduate research participation programs at Argonne and other DOE laboratories have proved very effective in sustaining student interest in graduate study in science and engineering and subsequent careers in research. The Science and Engineering Research Semester program, conducted during the academic year, is developing rapidly as a valuable alternative or supplement to summer programs. The academic-year and summer programs are both supplemented by numerous activities that further support student interest in graduate study and research.

The Lab Grad and Thesis Parts programs support graduate students conducting thesis research at national laboratories. Capacity at Argonne for participation in these programs and demand for appointments greatly exceed the number of appointments currently being made.

Table VI.3 Participation in Science and Math Educational Programs

Programs	FY 1994 Total	FY 1994 Under-represented Minorities[a]	FY 1994 Women	FY 1995 Total	FY 1995 Under-represented Minorities[a]	FY 1995 Women	FY 1996 Projected Total
Precollege Students							
Instructional Outreach Vehicle	11,500	3,500	5,000	16,595	8,752	8,466	16,000
Student Conferences	612	190	400	374	144	374	400
Boy Scouts/Explorers	72	3	24	69	-	29	70
Scientific Instrumentation	57	12	27	62	17	25	-
DOE High School Honors	54	4	23	56	8	19	-
Research Apprenticeship	69	16	28	68	10	33	-
Research Participation	32	4	17	26	6	12	-
Chicago Science Explorers	31,650	30,068	15,825	34,410	29,248	17,200	2,334
Precollege Teachers							
National Science and Technology Council — Science Teacher Enhancement Program	45	7	22	35	9	28	-
Teacher Conferences/Workshops	150	53	70	52	5	27	-
Argonne Community of Teachers	62	18	33	80	8	36	80
NSF/National Teacher Enhancement Program	30	7	22	28	3	21	30
Internet Teacher Training	200	22	110	427	55	243	900
DOE Teacher Research Associates	44	9	15	32	4	7	30
Chicago Science Explorers	1,055	369	897	1,147	458	917	500
Microscale Chemistry	-	-	-	76	4	46	50
Undergraduate Programs							
Summer Student Research Participation	249	52	82	215	38	62	200
Science and Engineering Research Semester	132	14	40	123	10	37	124
Instructional Laboratory	384	50	200	265	30	143	300
Graduate Student Fair	587	96	195	386	50	127	-
Undergraduate Research Symposium	152	-	-	157	-	-	157
Graduate Programs							
Laboratory Graduate/Thesis Graduate Students	160	7	42	155	7	46	150
Postdoctoral Fellows	133	2	22	151	4	22	150
Faculty Programs							
Faculty Research Participation	60	6	11	48	7	9	35
Sabbatical Leave	17	-	-	13	-	1	15
Faculty Research Visits	29	1	5	30	1	4	30
Diversity Initiatives							
Student Interdisciplinary Research Training	-	-	-	-	-	-	20
Community College Student Placements							
Cooperative Education	-	-	-	5	5	0	5
Student Research Participation	-	-	-	3	3	1	6

Table VI.3 Participation in Science and Math Educational Programs (Cont.)

Programs	FY 1994 Total	FY 1994 Underrepresented Minorities[a]	FY 1994 Women	FY 1995 Total	FY 1995 Underrepresented Minorities[a]	FY 1995 Women	FY 1996 Projected Total
Enrichment Activities							
Exploring the Internet (Community College Students)	-	-	-	30	30	19	30
Biotechnology Procedures (Community College Students)	-	-	-	30	30	19	30
Environmental Enrichment (Community College Students)	-	-	-	30	30	19	30
Clemente School (Precollege)	-	-	-	16	15	4	20
SOAR Project (Precollege)	-	-	-	15	15	9	15
Urban Engineering (Precollege)	-	-	-	42	42	25	40
Navigating through Cyberspace	-	-	-	-	-	-	15
Faculty Conferences[b]							
Partnering with Historically Black Colleges/Universities	-	-	-	54	38	14	-
Community College Regional Conference	-	-	-	34	14	14	-
Partnering with Hispanic-Serving Institutions and Native American Tribal Colleges	-	-	-	-	-	-	100

[a]Underrepresented minorities include Afro-Americans, Hispanics, and Native Americans.

[b]Excludes Argonne participants.

Two major programs that supplement all of the above programs in important ways — Workshops/Institutes/Conferences and the National Instrumentation Sharing Program — will continue with a full calendar of activities. All Argonne programs emphasize participation by women and underrepresented minorities, an emphasis that will increase in the planned expansions to include educational institutions such as technical institutes.

2. Precollege Programs

High school teachers participate in research at Argonne through the Teacher Research Associates Program. Each summer about 30 teachers receive an eight-week experience with Argonne scientists, supported by a stipend and travel allowance. Funding from the National Science Foundation supports a structured summer program for more than 30 additional teachers. Many teachers benefit from the National Instrumentation Sharing Program when they bring their classes to visit the Laboratory.

3. Undergraduate Programs

Argonne offers two major programs for undergraduates. In the Summer Student Research Participation Program, some 200 undergraduates from approximately 150 institutions and nearly all states of the union come to the Laboratory for 10-week summer experiences. The Science and Engineering Research Semester Program provides undergraduates with additional opportunities for research participation during the academic year.

Special effort is given to recruiting female and minority students for both of these programs.

The Science and Engineering Research Semester Program is one of the most visible and effective DOE programs offered by the Laboratory. Faculty endorsements and student interest have been consistently high, and the program takes advantage of unique administrative approaches. The program focuses on developing courses and seminars on subjects taught on few U.S. campuses. Special efforts are made to bring participants in this program into contact with faculty visitors and others involved in research collaborations at Argonne, for purposes such as discussing opportunities at graduate schools.

Argonne holds a one-day Graduate Student Fair in Science and Engineering in the fall for participants in the Science and Engineering Research Semester and for other students from midwestern universities and colleges. Over 400 students and approximately 120 faculty from graduate departments in science and engineering participate, and all have been enthusiastic.

New initiatives are increasing the diversity of participants and institutions involved in Argonne educational programs. One effort, aimed at community colleges and technical institutes, provides research associateships, internships, and short-term appointments for students and faculty members.

The Student Interdisciplinary Research Training Program provides educational experiences for freshmen and sophomores from predominantly minority institutions, including historically black colleges and universities and institutions serving Hispanics and Native Americans. Workshops and conferences facilitate dialogue and promote scientific collaborations between faculty from predominantly minority institutions and Argonne scientists.

4. Graduate, Postdoctoral, and Faculty Programs

Graduate students participate in research at Argonne via three types of appointments: (1) Lab Graduate, (2) Thesis Parts, or (3) Guest. A Lab Graduate appointment provides tuition payments and a monthly stipend for the duration of research at the Laboratory leading to an advanced degree. A Thesis Parts appointment supports short visits to use laboratory facilities. The student receives *per diem* and travel expenses. Guest appointments give students access to laboratory facilities but no financial aid.

Graduate students participate in specialized laboratory short courses and workshops through the Workshops/Institutes/Conferences program or the National Instrumentation Sharing Program. Postdoctoral positions at Argonne are managed completely by the Laboratory's research divisions.

At present, faculty from colleges and universities are eligible for two research participation programs at Argonne. The Faculty Research Participation appointment involves a ten-week summer research appointment with an Argonne scientist, supported by a stipend and travel allowance. Longer sabbatical appointments for faculty are possible through Faculty Research Leaves, which are supported primarily by research funding.

The largest numbers of faculty participate in programs at Argonne through workshops, institutes, and conferences or (with their laboratory classes) through the National Instrumentation Sharing Program. Both of these avenues are also important for student participants.

Workshops, institutes, and conferences focus on a wide variety of presentations, demonstrations, and discussions based on major experimental facilities and recent scientific research at the Laboratory. Each year, 25 to 30 events are scheduled. They are directed at graduate students and faculty. Undergraduates holding research participation appointments at the Laboratory are also encouraged to attend. Over 2,000 individuals participate each year. Women and minorities are particularly encouraged to attend, and one or more events each year are designed with these groups specifically in mind.

Argonne's National Instrumentation Sharing Program helps to provide modern instrumentation to U.S. colleges and universities. Whenever possible, research-grade equipment

located anywhere at the Laboratory is made available to faculty, students, and particularly graduate students involved in thesis research. A central clearinghouse coordinates this endeavor.

C. User Facilities

Argonne operates a variety of important scientific facilities for use by researchers from universities and industry who are pursuing their own studies and for research specifically being conducted by Laboratory staff for DOE and other government agencies. The resulting interactions with outside users lead to highly productive collaborations. Some of these Argonne facilities are unique; all provide services that are not readily available from private sources in the United States.

Outside researchers interested in using Argonne facilities submit proposals that are reviewed by an advisory committee including representatives from universities or industry. The advisory committee confirms that each proposed investigation is compatible with Argonne's basic work for DOE and has high scientific merit.

For nonproprietary research that will be published in the scientific literature, use of Argonne facilities is generally free (though there may be some charge for unusual ancillary services, such as fabrication of special equipment). Researchers from universities make particularly heavy use of this generous scientific support. Users from industry who propose proprietary research can also receive approval if their research is compatible with basic DOE programs and they pay fees covering the full cost of their time at the facilities. However, many industrial users conduct nonproprietary scientific research on the same basis as do academic researchers.

The breadth and diversity of support for outside users provided by national laboratories often are not fully appreciated. Table VI.4 describes Argonne user facilities that have been officially designated as such by DOE. The numbers of experimenters in FY 1995 are broken down according to whether the users are from a government laboratory (including state laboratories), a university, or industry.

In highly abbreviated terms, these Argonne facilities provide the following important scientific capabilities:

- *Advanced Photon Source (APS):* Became operational in 1996, providing super-intense 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 (IPNS):* Accelerates protons to obtain neutrons, which are particularly valuable for the study of materials by analyzing the motions and structures of atoms.

- *Argonne Tandem-Linac Accelerator System (ATLAS):* Accelerates ions of heavy elements for studies of their reactions, to advance basic understanding of the properties of atoms and atomic nuclei.

- *High Voltage Electron Microscope-Tandem Accelerator Facility:* Interfaces two electron microscopes (one high voltage, one intermediate voltage) with two ion accelerators for *in situ* studies of ion irradiation and implantation effects in metals and alloys, semiconductors, and ceramics.

Further information on the capabilities of these user facilities and procedures for obtaining access to them can be obtained through this address:

Physical Research Program
Building 221, Room B111
Argonne National Laboratory
Argonne, IL 60439
Telephone: (708) 252-6784

Virtually all facilities at Argonne can be made available to outside users for suitable purposes.

Table VI.4 Experimenters at Designated Argonne User Facilities — FY 1995

	Laboratory[a]		University		Industry		Other[b]		Totals	
	No.	*% Use*	No.	*% Use*	No.	*% Use*	No.	*% Use*	No.	*% Use*
IPNS	71	*36*	101	*51*	13	*6*	14	*7*	199	*100*
ATLAS	61	*19*	177	*55*	-	-	85	*26*	323	*100*
High Voltage Electron Microscope-Tandem Accelerator Facility	34	*33*	54	*62*	2	*1*	16	*4*	106	*100*

[a]The "Laboratory" category includes researchers from Argonne and all other federal and state laboratories in the United States.

[b]The "Other" category includes foreign laboratories and institutes.

Critical Success Factors

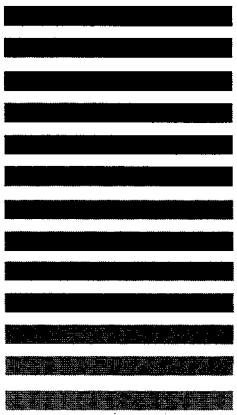
The Department of Energy's 1994 *Strategic Plan* identifies four critical factors that determine the success of the Department, including its laboratories:

- Management practices,
- Communication and trust,
- Human resources, and
- Environment, safety, and health.

As described in the following chapters, Argonne is an active partner in the Department's efforts to achieve continuous improvement in each of these areas. (The brief discussion of communication and trust is included in the lead chapter on "Management Practices.")

In addition, as a government-owned national laboratory featuring major research facilities, Argonne considers its site and facilities to be another critical success factor. Accordingly, Chapter X is devoted to the Laboratory's plans for them.

Information management is also very important to the Laboratory. The Laboratory's innovations and improving performance in this fast-moving arena are addressed in a separate chapter (Chapter XI).



VII. Management Practices

In its consideration of governance and organization issues affecting DOE and its national laboratories, the Galvin Task Force report (pp. 55-57) states that "in private industry it is virtually axiomatic that a dedicated, empowered, quality program will generate better than 20% cost improvements with greater values in significantly improved quality of output of services, engineering, and product." In that spirit, Argonne has been aggressively developing and applying management practices that help to achieve the highest possible quality in its work, to maximize efficiency and productivity, and to contain operating costs. This chapter describes the vision guiding Argonne's management improvement initiatives, identifies the goals and strategies for achieving that vision, outlines the Laboratory's performance measurement system, and summarizes the productivity and cost savings resulting from the Laboratory's diligent and aggressive management of operations.

A. Vision and Purpose

Argonne's management systems and practices contribute importantly to achieving its goal of being a model multiprogram R&D institution, one that is effectively organized and thoroughly committed to performing its missions with a focus on customers and stakeholders, including DOE, the public, and industrial partners; that serves as a trusted neighbor and a resource for its community and the economies of Illinois and the Midwest; that achieves cost-effectiveness through a continual commitment to improving its business and operational practices; and that maximizes the contributions of its human resources through participation, teamwork, and recognition of performance.

B. Goals and Strategies

1. Focus on the Customer

Argonne serves many customers, including industrial R&D partners, educational institutions, and users of its major research facilities. The DOE program offices that fund the Laboratory's R&D are its largest direct customers. These DOE offices represent a larger national community of end-user customers who use and benefit from Argonne's work. The Laboratory's goal is to deliver R&D products and to manage and operate its facilities in a way that achieves a consistently high degree of satisfaction among all its customers. DOE has recognized the Laboratory for its cooperation with DOE and outside organizations in activities promoting DOE missions. These activities include support of the Chicago Operations Office in regional business outreach; collaboration with DOE in hosting conferences (such as one for suppliers to the automotive industry); continuing interactions with regional, state, and local economic development organizations (such as the Illinois Coalition, the North Business and Industrial Council, the Valley Industrial Association, and the East-West Corporate Corridor Association); and continuing support of the Chicago Manufacturing Technology Center.

For DOE, Argonne provides long-term support in the areas of program planning and management, taking advantage of the Laboratory's experience and knowledge of program history.

Management and operation of scientific user facilities constitute a core competency of the Laboratory. At the heart of that competency is a deep commitment to serving the needs of scientific communities in universities and industry.

Argonne recognizes that timely and responsive internal support services are critical to the cost-effectiveness of its R&D programs. With leadership from senior management, service organizations across the Laboratory are making coordinated efforts to learn the requirements and priorities of internal customers.

2. Organizational Alignment

An important Argonne goal is to maintain a flexible organizational structure that continuously realigns itself to serve customers' needs. Laboratory senior management periodically reviews each major organizational unit and each major R&D program to ensure that they are aligned with missions, that internal organizational conflicts are avoided, and that responsibilities and authority cascade consistently throughout the organization. For example, a recent organizational realignment dissolved a separate support services division and reassigned its elements to other existing divisions with similar functions, thereby eliminating an entire divisional management structure, creating synergies, increasing efficiency, and generating annual cost savings of approximately $750,000.

The Laboratory's systematic organizational review is shaping the organizational structure at the Advanced Photon Source (APS) for better service to a rapidly growing community of future users as the facility shifts from construction to operations. To ensure that operations are fully responsive to user interests, a special committee represents the user community, a peer review board evaluates users' proposals, and a research directorate facilitates interactions between the APS and its collaborative access teams.

3. Improving Communications

In dealing with its customers and stakeholders, the communities it serves, and its employees, Argonne strives to achieve a high degree of trust and confidence through open, accurate, timely, and credible communications that foster a sense of participation. Multiple strategies are employed to improve these communications.

The Laboratory has long maintained regular communications with the general public and with customers and stakeholders in business and industry, in national and international scientific communities, and throughout government, as well as within DOE. The primary means of communication are the general and specialized news media (through press releases, media briefings, interviews, and opinion/editorial articles) and direct forms of communication and contact (publications, site tours, conferences, speeches, and special events). Argonne management meets regularly with elected officials and community groups from surrounding areas to keep them informed about Laboratory activities and to obtain feedback on their interests and concerns. Community meetings held by DOE and Argonne in both Idaho and Illinois are useful in communicating with diverse stakeholders. Argonne's waste management and environmental remediation programs increasingly involve communication with the Laboratory's neighbors.

To increase communication and outreach to business and industry regarding opportunities at the Laboratory, Argonne has restructured its management communications. Communications specialists now work directly with Argonne program managers to enhance their program development and outreach activities.

Argonne aims to provide strong, continuing information and accessibility to the public. Strategies take several forms. A flow of public visitors to both the Illinois and Idaho sites is maintained through an active public relations program. Each site hosts an extremely popular open house. Drawing on the Chicago metropolitan area, the most recent Argonne-East open house attracted 18,000 visitors to more than 150 exhibits and demonstrations. A speakers bureau arranges invited speakers for local community groups. Various publications inform the public about the partnership between DOE and Argonne, Argonne's programs and accomplishments, and the Laboratory's role in surrounding communities. These activities will be augmented throughout 1996 with a series of

special events commemorating Argonne's 50th anniversary.

Argonne is increasingly communicating via the World Wide Web and other Internet vehicles. In the fall of 1994, the Laboratory began posting news releases on its Web server. Subsequent additions include text versions of Laboratory publications (with multimedia versions planned), news releases by senior managers, and detailed descriptions of the Laboratory's programs and its scientific and technical capabilities. A capabilities database, searchable by key words, is linked directly with the Laboratory's Industrial Technology Development Center to give industrial firms easy access to the Laboratory.

Another Argonne strategy, related to DOE's openness initiative, aims at facilitating access to the Argonne sites by reducing unnecessary security barriers and by increasing public understanding of the Laboratory. The Laboratory welcomes requests for information by local communities.

Important elements of Argonne's strategy to enhance its internal communications are embodied in its information management initiatives, as discussed in Chapter XI.

To measure the impact of its communications programs, Argonne plans to survey the attitudes of both employees and residents of nearby communities regarding the Laboratory and its critical success factors, including communications and trust. Argonne is also working with other DOE laboratories to develop a coordinated outreach program emphasizing the role of science in American society.

4. Participatory Strategic Planning

Strategic planning at Argonne has always included a strong bottom-up contribution. Development of new scientific and technical initiatives by individual R&D programs is encouraged. Senior management provides leadership by establishing goals, priorities, and resource allocations and by implementing actions.

The Laboratory is broadening organizational involvement and coordination in developing its strategic plan. The main goals are to align the Laboratory's visions, goals, and strategies more closely with those of DOE and to communicate those strategic positions more effectively, both inside and outside the Laboratory. In the present *Institutional Plan* document, Chapter III ("Strategic Plan") and Chapter IV ("Major Initiatives") are the most direct reflections of this strengthened strategic planning process.

5. Improving Business and Operational Practices

The quality and cost-effectiveness of Argonne's business and operational practices contribute directly to the Laboratory's success in performing its R&D missions and providing value to its sponsors, customers, and stakeholders. Argonne's goal is premier status in its business and operational practices, viewed both from DOE's perspective as the steward of public funds and from the perspective of U.S. industry and other final beneficiaries of the Laboratory's research. Key objectives are to institutionalize continuous improvement practices; to improve functional work processes by reducing cycle times and eliminating tasks that do not add value; and to increase the use of measures and metrics as the basis for tracking, assessing, and comparing performance.

Strategies for improving Argonne's business and operational work processes require both a methodology and a means of implementation. The Laboratory's evolving methodology, which comes in part from Motorola Corporation, is based on organizational mapping and analysis. For a given work process, this methodology involves establishing benchmarks, identifying the baseline of current practice, comparing Argonne's practices with those of other organizations to help establish goals for improvement, and analyzing the current process in depth to identify specific improvements that are possible within the constraints of statutory requirements and available resources. For

example, the Laboratory's plant facilities and services division recently reworked several of its operational processes and realigned its organizational structure to become more cost-effective and responsive to its customers. Among the benefits achieved were a reduction of more than 50% in the division's overtime hours and a reduction of 18% in the average unit cost of space provided to other divisions. Setting benchmarks for the Laboratory's custodial functions led to changes in practices that are estimated to provide $800,000 in cost avoidance in FY 1996, along with a 17% reduction of staff.

As demonstration projects for implementing the Laboratory's team approach to process improvement and problem solving, Argonne organized pilot process improvement teams to address the disposal of low-level radioactive waste; the receipt and distribution of materials; facilities engineering for service request projects; hiring; and procurement. Implementation of team recommendations has resulted in significant improvements. For example, continuing improvements in facilities engineering at the Laboratory resulted in further reductions in the fraction of service request projects behind schedule, to 13% in FY 1996. Projects were completed within cost estimates 92% of the time.

Argonne has implemented diverse quality management and improvement initiatives at the grass roots organizational level. For example, internal processes of the procurement department are benefiting from the establishment of quality teams. Elsewhere, the Laboratory's performance on construction and environmental projects improved relative to schedule by 24% in FY 1996, one year after reengineering of the project management system.

Integral to Argonne's strategy for strengthening and improving its business and operational practices is the use of measures and metrics for tracking, assessing, and improving performance. The Laboratory's business and operations functional organizations have identified performance measures most appropriate for establishing benchmarks, tracking progress toward goals, estimating efficiency and cost-effectiveness, confirming compliance with applicable directives and regulations, and gauging the satisfaction of sponsors and other customers. The Laboratory has implemented higher-level performance metrics suitable for oversight and assessment by senior management. As required by the new prime contract governing operation of Argonne by the University of Chicago, 90 performance measures in 15 functional areas covering the Laboratory's operations are now being systematically tracked and reported.

Management information systems are key to improving operational practices. In 1993 Argonne launched an initiative to provide a more cost-effective computing environment for its laboratory-wide management information systems, which at that time were largely centralized on an IBM mainframe computer. By February 1996, all these systems had been moved to decentralized, networked machines. Argonne's management information systems now capitalize on commercial relational database software operating on personal computers and high-performance workstations. This new computing environment allows the Laboratory to exchange data electronically with vendors, to provide easy internal access to data, to expedite work flows, and to use scanned images of documents such as resumes and material safety data sheets.

6. Empowering the Work Force

Argonne's success in delivering relevant and valuable R&D depends fundamentally on its ability to utilize and motivate its human resources. The interests of employees and the goals of the Laboratory must coincide and be consistent with Laboratory practices. To achieve these goals, Argonne is adopting strategies to motivate employees by providing them with wider opportunities for participating in improvement of work processes; by recognizing and rewarding their contributions and commitment more fully; and by providing them with the knowledge, tools, and support that enable them to take positive action.

Argonne's use of cross-organizational teams to improve work processes is encouraging involvement by people at many levels of the organization. The Laboratory's pilot process improvement teams have demonstrated that cross-organizational teams can open new lines of communication and build effective working relationships that cross traditional organizational boundaries.

Argonne provides diverse quality education and training programs that help employees acquire the knowledge, tools, and skills they need to strengthen their management practices. Current programs take advantage of the executive MBA program at the University of Chicago, off-site management instruction, and various on-site offerings. In partnership with Motorola University, Argonne offers its employees a selection from the catalog of courses that Motorola routinely offers its own employees. The Laboratory also takes advantage of Motorola's expertise in customized training programs. For example, Motorola helped Argonne develop an on-site two-day quality management training program for all supervisors and managers, including those in programmatic R&D divisions. The program focuses on building high-performance teams through problem solving.

C. Measuring Performance

The new prime contract for operation of Argonne by the University of Chicago — effective from June 1995 through September 1999 — requires that the Laboratory's performance be measured systematically, thereby motivating and facilitating continuous improvement. The new system for measuring the Laboratory's performance, which covers both science and technology programs and support operations, determines the performance fee that the University receives, as well as a bonus pool for employees. This performance-based contracting is part of DOE's strategic management system, which, in addition to performance evaluation, encompasses strategic planning, budget formulation, and budget execution across all Department activities. Argonne's performance evaluation system is aligned with and supports the strategic missions and goals of both the Laboratory and DOE.

1. Scientific and Technical Programs

The very nature of scientific inquiry — its complexity, duration, and examination of the unknown — argues against the establishment of narrowly quantitative criteria for evaluating the quality of scientific research. Traditionally, a system based on review by scientific peers has been used to guide scientific research and establish standards for that research. In keeping with this tradition, peer review processes are used to evaluate Argonne's science and technology programs. Goals, success indicators, and performance measures used to evaluate the Laboratory's science programs, which are sponsored primarily by DOE's Office of Energy Research, are somewhat different from those used for the technology programs, which are sponsored by DOE's assistant secretaries for technology development.

The DOE evaluation of Argonne's performance uses both reviews conducted at the behest of various management levels within the Department and reviews of Laboratory programs conducted by visiting committees under the auspices of the University of Chicago. DOE program managers generally carry out periodic reviews of the programs they fund, often with the assistance of independent technical experts. These reviews, translated into the Laboratory's prespecified performance measures, are a primary input into the Department's evaluation of Argonne's scientific and technical performance. Also considered, when available, are inputs from formal advisory committees and *ad hoc* review panels reporting to DOE secretarial-level officers.

The Science and Technology Advisory Committee of the Board of Governors for Argonne oversees the University of Chicago visiting committee review process, under which each major science and technology program at the Laboratory is reviewed on a cycle of 12 to

24 months. The members of the independent review committees are drawn from the external scientific, engineering, and business communities, in consultation with DOE program managers. Their assessments are also a primary input for DOE's assessment of Argonne's scientific and technical performance.

2. Support Operations

Argonne's support operations encompass 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 environmental compliance, safety, and health programs. Altogether, 15 functional areas are distinguished within support operations. Goals, success indicators, and performance measures have been developed for each area and are included in the prime contract as a basis for evaluating the performance of support operations.

For each of 90 contractual performance measures for support operations, a specific scale translates measured performance into an adjectival rating (outstanding, excellent, good, marginal, or unsatisfactory). Weighted adjectival ratings generate a composite rating for each of the 15 functional areas and ultimately for support operations as a whole.

At the end of the first year under the new prime contract, the University of Chicago will deliver to DOE a self-assessment of Laboratory support operations that will include performance results for the 90 contractual performance measures. These results will provide an important, but not exclusive, basis for DOE's annual appraisal of the performance of support operations. The final overall appraisal by the DOE contracting officer can also consider the results of (1) business reviews, (2) ES&H (environment, safety, and health) and security appraisals, (3) any audits conducted by the DOE Inspector General or the General Accounting Office, (4) reviews of the Laboratory triggered by particular events, and (5) any other assessments deemed relevant.

D. Overhead Cost Reduction and Improved Productivity

For more than a decade, Argonne has maintained a disciplined, methodical system for reviewing and controlling overhead costs. The Argonne Overhead Management (AOM) process has contributed significantly to achievement of a relatively flat overhead rate over the past several years, a time when DOE initiatives exerted great cost pressure. The AOM process involves a systematic, detailed, bottom-up methodology for establishing functional area budgets by using modified zero-based concepts. The Laboratory's review for FY 1996 resulted in targeting the following areas for substantial cost reductions: building and utility systems, custodial operations, ES&H programs, and quality assurance.

To further improve Argonne's cost-effectiveness, the Director's Cost Savings Committee identifies ways to improve productivity, eliminate redundancy, reduce costs, and generally improve operational performance without compromising the quality of products and services that the Laboratory provides in support of R&D. The committee is chaired by the laboratory director and includes senior research managers. Since March 1995, this committee has launched a number of beneficial initiatives, including reorganization of the Laboratory's office for oversight of ES&H and quality assurance; development of an outsourcing evaluation methodology and its successful application to custodial services; development of a retirement incentive program; and development and application of higher-level productivity and efficiency metrics for scientific programs and support operations.

Delayering and realignment of Laboratory organizations have contributed substantially to cost reduction, particularly through increased productivity and improved spans of control. Mentioned already were restructuring and realignment of the oversight organization for ES&H and quality assurance and dissolution of a separate support services division. In addition,

entire layers of management were eliminated in the human resources division and in several departments of the plant facilities and services division. Spans of control were substantially widened through reduction in second-echelon management in the budget office and media services department.

From FY 1995 to FY 1996, Argonne's initiatives in productivity improvement and cost reduction combined to eliminate 110 staff positions and reduce overhead costs by 10% ($14 million), without compromising the quality of products and services provided in support of R&D. These savings represent about 60% of the $23 million savings goal that Argonne set as part of the Secretary's five-year initiative in response to the report of the Galvin Task Force.

Argonne's accomplishments in containing overhead costs and in maintaining an efficient balance between scientific and support personnel reflect a sustained effort over the past decade. These accomplishments place the Laboratory among the leaders of DOE's multi-program laboratories. Efforts toward further savings will continue. Table VII.1 reports Argonne's current performance and future goals in terms of DOE's three high-level productivity measures.

Table VII.1 Productivity Metrics

	FY95	FY96	FY97	FY98	FY99	FY00
Research-to-Support (Labor Dollar) Ratio[a]	2.09	2.13	2.17	2.22	2.27	2.27
Technical Labor on Research (%)[b]	84.6	85.0	85.0	85.0	85.0	85.0
Average Operating Cost per Research FTE[c]	137	135	132	129	127	125

[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.

Argonne already has achieved a highly favorable research-to-support ratio as a result of past efforts; further improvements will be nominal, reflecting continuing overhead cost containment and streamlining initiatives. Similarly, the percent of technical labor within the Laboratory's research organizations, achieved through years of management effort, is now considered at an optimal balance that will be maintained in the future. The favorable average researcher cost will be contained to grow at less than the general rate of inflation.

VIII. Human Resources

Quality of technical staff is the primary determinant of the performance of a research and development laboratory. Argonne's success depends most on its ability to employ and motivate creative scientists and engineers. The objectives of the Laboratory and the interests of technical staff must coincide and be consistent with Laboratory practices and programmatic efforts. This matching of interests and objectives creates the environment needed to maximize productivity. These principles apply as well to operations staff supporting the work of the Laboratory's scientists and engineers.

A. Laboratory Personnel

Total Argonne employment is projected to decline from 4,930 FTEs in FY 1996 to 4,720 FTEs in FY 2002 (see Table XII.2). Recruitment of Argonne staff is administered by human resources professionals, who begin by using standard techniques such as close coordination with college placement programs, extensive advertising, and liaison with professional societies. To attract outstanding technical staff, the Laboratory also maintains several special employment programs that focus on specific types of employees. These programs include the following:

- The Argonne Fellow Program, which attracts outstanding scientists and engineers for extended periods of work at the Laboratory
- The Argonne Scholar Program, which attracts outstanding recent recipients of doctorates
- The Predoctoral Program, which attracts outstanding women and minority recipients of recent MS degrees
- The Student Exchange Program, which exchanges graduate students between the United States and France, Germany, and Japan
- The National Consortium for Graduate Degrees for Minorities in Engineering, which encourages U.S. minority students to seriously consider advanced study in engineering
- The Maria Goeppert-Mayer Distinguished Scholarship, which attracts outstanding women scientists and engineers to the Laboratory
- The Women in Science program, which promotes the hiring and professional development of women scientists at the Laboratory
- The Temporary Services Program, which provides quality temporary office personnel to the Laboratory

The Laboratory's special efforts to recruit minority and women scientists and engineers are described in more detail in Section VIII.C.

Argonne's employees are highly educated. Table VIII.1 summarizes the academic degrees held by permanent staff at the end of FY 1995.

Table VIII.1 Academic Degrees of Argonne Staff[a]

Category	PhD	MS/MA	BS/BA	Other[b]	Total
Professional Staff					
Scientists/ Engineers	751	404	381	171	1,707
Management and Administrative	99	148	188	159	594
Support Staff					
Technicians	-	3	63	563	629
All Others	-	1	59	1,154	1,214
Laboratory Total	850	556	691	2,047	4,144

[a]Number of full- and part-time employees at the end of FY95. Scientists are included in the management and administrative category if that is their primary duty.

[b]Associate level degree or less.

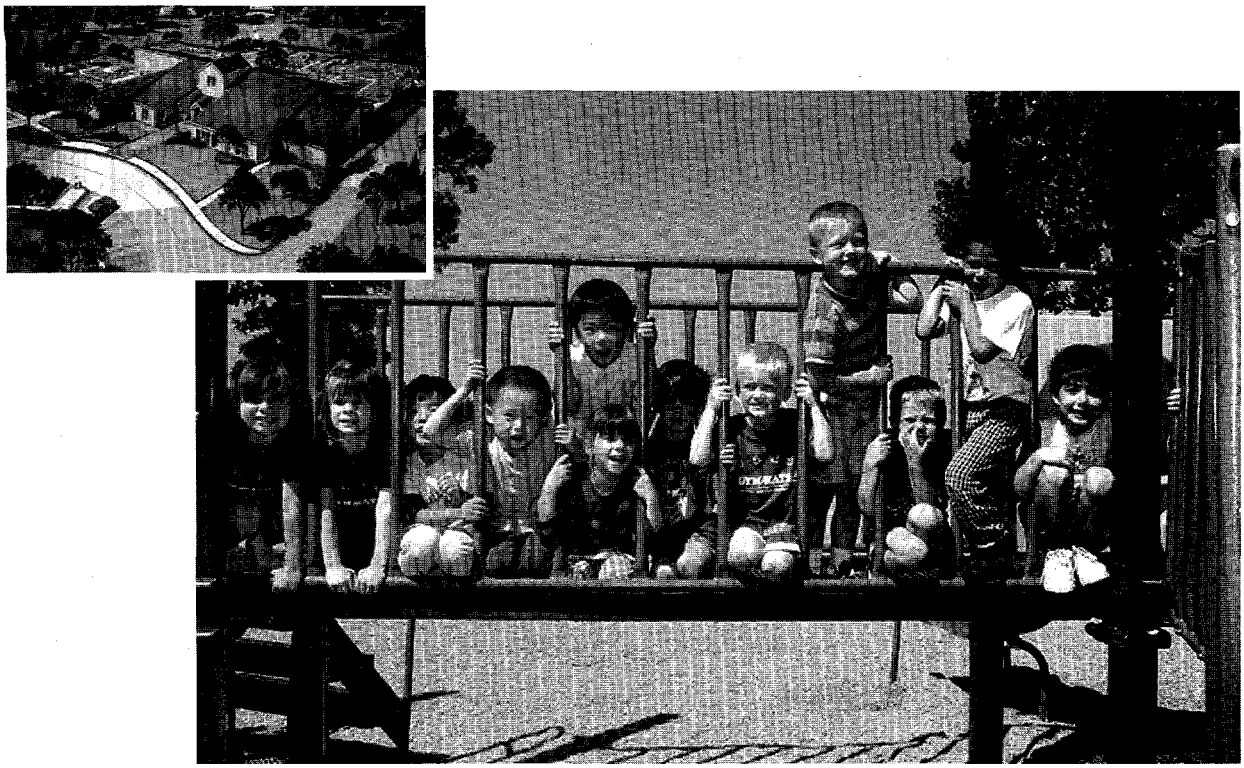


Figure VIII.1 The Argonne Child Development Center satisfies its customers.

Argonne's commitment to supporting its working families is symbolized by the Argonne Child Development Center, which opened in September 1992. The Center provides employees with top-quality day care on-site. It can accommodate 76 children from infants through five years of age in a safe and inviting environment with appropriate child development programs. Argonne continues to offer employees an arrangement whereby pretax dollars can be used to pay for child care expenses.

Officials of the University of Chicago signed a new contract in June 1995 to operate Argonne for DOE. The contract includes a Total Compensation Cost Containment Pilot Program, under which the Laboratory will have greater flexibility to establish pay and benefits for its employees, and DOE oversight will be less restrictive. In each year of the contract, the Laboratory is obligated to reduce total compensation by at least 1% of actual compensation in the prior year. Successful attainment of this obligation allows distribution of payments from an employee bonus pool.

Argonne continues to pursue initiatives to control the cost of its benefit plans for employees while remaining competitive in the marketplace. Recent changes in paid leave practices will especially help the Laboratory meet its annual cost containment obligation. Argonne continues to support innovative benefits in areas such as employee-paid long-term-care insurance and overseas emergency medical assistance. In January 1996 the Laboratory added to its health care plan a preferred provider option that is expected to reduce total plan costs by about 10% in its first year of operation.

Argonne offered two early retirement incentive programs in FY 1995. Nearly 200 employees accepted these offers, lessening the impact of subsequent reductions in force at the Laboratory.

Argonne's on-site medical program evaluates employees' health and provides immediate services for occupational injury or illness. Responsibilities of the program include management of occupational cases; periodic medical surveillance of workers potentially exposed to physical, chemical, or biological hazards; and comprehensive health screening, supplemented by preventive health and wellness programs. Intense management of workers' compensation claims, integrated with outside medical services and the Laboratory's environment, safety, and health activities, has yielded impressive results in both safety statistics and insurance costs. The Laboratory provides on-site psychological counseling, an employee assistance program, and a substance abuse program supporting a drug-free workplace program.

The Laboratory has enhanced communication between employees and management through a program to elicit concerns and suggestions from employees. Awards are given for suggestions that save the Laboratory money or time or that help to maintain excellent performance in the area of environment, safety, and health.

B. Enhancing Staff Capabilities

Professional growth is an integral aspect of careers at an organization such as Argonne National Laboratory. Activities contributing to the professional growth of researchers are so diverse that they defy capsule description. The annual schedule for approximately 1,000 on-site technical seminars suggests the extent of some of these activities. In addition, the Laboratory has implemented many special programs to increase or maintain the capabilities and vitality of its staff. These programs are part of an institutional culture that highly values employee development and organizational processes that foster it.

The Laboratory's formal organization review process has a five-year planning horizon and is integrated with institutional planning for initiatives, programs, research divisions, and support operations. As part of this process, total staffing implications are derived. Formal discussions take place regarding progress in attracting and developing minority and women staff members. Employees whose performance demonstrates the greatest potential for advancement are identified; given broadening assignments; and, where appropriate, channeled toward formal educational opportunities such as the executive MBA program described near the end of this chapter. Provisional plans for successions to key jobs are maintained.

Argonne provides formal professional development for its managers and supervisors. Participants learn about managerial roles and responsibilities at the Laboratory and about resources available to them. Instructional topics include organization planning and management; research and the business partnership; finance; site management and services; designing and developing a research or scientific facility; project management; building high-performance work teams; managing a diverse work force; and equal employment and affirmative action responsibilities. A communications-based instructional series for supervisors addresses topics such as working styles, communication, team building, and motivation.

Argonne continues to refine its computerized management system for identifying employee training requirements and tracking training received. Each employee answers a comprehensive questionnaire on job hazards to determine required training. A recent improvement in the system allows on-line data entry and course enrollment.

The Laboratory offers employees a broad range of on-site educational programs that contribute to job skills. These courses range from very specific topics (such as training in basic reading and English as a second language) to courses in general disciplines (such as computer usage, professional secretarial skills, and management methods). Also addressed are diverse special topics, such as presentation techniques, technical writing, and records management. Women participate in Argonne's educational assistance and on-site training programs in numbers proportionally greater than

their representation in the Laboratory work force.

To further emphasize the high value that Argonne places on employee development, the Laboratory's educational assistance plan has been revised to permit prepayment of expenses, lessening financial impacts for employees furthering their education. Schools now bill Argonne directly for tuition and related fees.

Argonne has two special programs through the University of Chicago, the institution that operates the Laboratory under contract to DOE. In a typical year, two middle- or upper-level Argonne managers are selected for the University's 16-month executive MBA program. Participants retain their job responsibilities while attending classes every other Friday and Saturday. The other program provides 50% tuition remission to dependent children of regular full-time employees for courses taken at the University.

Argonne offers advanced executive development for its most senior managers through programs at universities and other off-site organizations. These programs allow interaction with other senior managers from a diversity of organizations and generally broaden management horizons.

C. Equal Employment Opportunity, Affirmative Action, and Diversity

Argonne has established a strong commitment to equal employment opportunity and strong policies to support that goal. The Laboratory's diversity and affirmative action programs are designed to provide a bias-free environment that attracts and retains the best possible employees, regardless of race, color, sex, national origin, age, religion, veteran status, or disability. Managers at all levels are fully committed to initiatives supporting equal employment opportunity and affirmative action. Through their actions, positive steps have been taken to increase the number of women and minorities in the work force and to ensure that equal employment is integral to the Laboratory's standard operating procedures.

Argonne has initiated many dynamic programs that support affirmative action and equal employment opportunity. The Laboratory programs described below help managers and supervisors in recruiting, advancing, and retaining a diverse work force.

1. Recruitment

Each year the Laboratory develops a recruitment plan targeted at colleges and universities with large female and minority enrollments. This formal basis for recruiting women and minorities has proved highly useful. For each position posted for external recruitment, the Laboratory has an explicit strategy to tap education and professional organizations with minority and female candidates. In addition, the Laboratory actively participates in annual conferences of scientific and engineering professional societies.

During FY 1996 Argonne will be attending the following career fairs and job placement activities:

- *American Indian Science and Engineering Society:* Annual National Conference/Career Fair
- *Massachusetts Institute of Technology:* Society of Women Engineers Career Fair
- *National Association of Minority Engineering Program Administrators:* Annual Meeting
- *National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc.:* Graduate Fellow Selection Meeting
- *National Organization of Black Chemists and Chemical Engineers:* National Conference and Career Fair

- *National Society of Black Engineers:* Annual National Conference and Career Fair
- *National Technical Association:* Annual Conference Technical Career Opportunity Fair
- *Society of Hispanic Professional Engineers:* National Career Conference
- *Stanford University:* Women and Minority Career Opportunity Fair
- *Society of Women Engineers:* Annual National Meeting and Student Conference
- *University of Illinois, Chicago Circle:* Minority Engineering Recruitment and Retention Advisory Board Meeting
- *Women in Engineering Program Advocates Network:* Annual National Conference

A further technique used by Argonne to improve recruitment and increase the number of women and minority applicants is the weekly distribution of job announcements to 132 selected organizations, including colleges and universities, community organizations such as the Urban League, and rehabilitation centers. In FY 1995, 40% of these organizations targeted minorities, women, and persons with disabilities.

In addition, the Laboratory places advertisements that target specific segments of the population. In FY 1996 ads are being placed in the following strategically targeted publications and newspapers:

- *Awards Program Booklet*, Society of Hispanic Professional Engineers
- *Careers and the Disabled*
- *Journal of the National Technical Association*, Spring and Summer Issues
- *National Organization of Black Chemists and Chemical Engineers*, Conference Program Book
- *National Society of Black Engineers*, 22nd Convention Program Book
- *Program Booklet*, Society of Women Engineers
- *Science*, Minority Issue
- *Science*, Women in Science Issue

Argonne employs a search firm specializing in the identification and recruitment of minorities and women. The firm is thoroughly briefed concerning the Laboratory's selection process and its commitment to equal employment opportunity. Referrals of candidates to Laboratory managers are closely monitored.

The Laboratory also takes advantage of its diverse internal work force. Current employees who are members of protected classes help to identify recruitment opportunities and potential candidates.

2. Preparation for Promotion

Women and minorities have made steady progress at Argonne, in both their overall numbers and their representation in management. Minorities represent 8% of the management work force, women 17%. Minorities account for 13% of the scientific and engineering population, women 12%.

Argonne recognizes that continuing education plays a key role in an individual's career development and advancement. The Laboratory provides tuition reimbursement to regular full-time employees who successfully complete college courses or degrees that can improve their skills, job development, and value to the Laboratory. In FY 1995 Argonne paid almost $800,000 for education assistance. Approximately 45% of the participants were women; 10% were minorities.

Table VIII.2 describes the current distribution of Argonne employees among various racial and ethnic categories.

Table VIII.2 Equal Employment Opportunity[a] (Number of Regular Employees at End of Fiscal Year)

FY 1990

Occupational Category	Total				Minority Total				White				Black				Hispanic				Native American				Asian/Pacific Islander			
	Male		Female		Male		Female		Male		Female		Male		Female		Male		Female		Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Officials and Managers[b]	379	90	43	10	26	6	4	1	353	84	39	9	3	1	3	1	3	1	0	0	1	0	0	0	19	5	1	0
Professionals	1417	84	265	16	167	10	21	1	1250	74	244	15	20	1	4	0	15	1	3	0	3	0	0	0	129	8	14	1
Technicians	465	91	45	9	34	7	3	1	431	85	42	8	16	3	1	0	8	2	1	0	4	1	1	0	6	1	1	0
All Others	541	47	614	53	110	10	114	10	431	37	500	43	84	7	71	6	20	2	27	2	2	0	6	1	27	2	10	1
Total	2802	74	967	26	337	9	142	4	2465	65	825	22	123	3	79	2	46	1	31	1	10	0	7	0	181	5	26	1

FY 1995

Occupational Category	Total				Minority Total				White				Black				Hispanic				Native American				Asian/Pacific Islander			
	Male		Female		Male		Female		Male		Female		Male		Female		Male		Female		Male		Female		Male		Female	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Officials and Managers[b]	117	66	59	34	4	2	5	3	113	64	54	31	1	1	4	2	1	1	0	0	2	1	0	0	0	0	1	1
Professionals																												
Scientists/Engrs.	1599	88	227	12	208	11	31	2	1391	76	196	11	14	1	5	0	19	1	3	0	2	0	0	0	173	9	23	1
Administrative	151	50	152	50	12	4	21	7	139	46	131	43	6	2	8	3	3	1	5	2	0	0	1	0	3	1	7	2
Technicians	561	91	53	9	53	9	6	1	508	83	98	16	26	4	2	0	14	2	0	0	3	0	1	0	10	2	3	0
All Others	574	45	694	55	116	9	129	10	458	36	565	45	87	7	86	7	22	2	28	2	3	0	5	0	4	0	10	1
Total	3002	72	1185	28	393	9	192	5	2609	62	1044	25	134	3	105	3	59	1	36	1	10	0	7	0	190	5	44	1

[a]Includes both the Illinois and Idaho sites. Percentages are calculated separately within each occupational category.

[b]In FY90 scientists who also had management responsibility were included in the Officials and Managers category; in FY95 they were included in the Professionals-Scientists/Engrs. category.

3. Welfare and Retention

Recognizing the importance of recruiting and retaining a diverse work force, the Laboratory has implemented several aggressive programs to ensure a work environment that is conducive to the growth of all employees.

The Laboratory funds and supports the position of Women in Science Program Initiator. The technical staff member holding this position is responsible for initiating, facilitating, and establishing activities that encourage the recruitment and retention of women scientists. She reports directly to the laboratory director, who supports the position at 30% of full-time employment. The Women in Science Program Initiator serves a two-year term.

The central purpose of Argonne's Cultural Diversity Advisory Committee is to increase awareness and appreciation of diverse populations at the Laboratory and to help all employees realize their fullest potential. The committee includes representatives from throughout the Laboratory. It supports a translator network of over 200 employees who can speak and write 34 foreign languages, including sign language. The committee generally aims to assist employees in overcoming work-related difficulties resulting from language barriers (for example, by providing courses in English as a second language and in basic reading). Through the Laboratory's Diversity Program Office, the committee sponsors activities in observance of all cultural commemorative events designated by presidential proclamation.

The committee also makes recommendations on compliance with the Americans with Disabilities Act and brings unresolved issues and special concerns to the attention of the laboratory director and the Laboratory's management council.

Argonne has made special efforts to retain a diverse work force by helping employees balance work and family responsibilities. Benefits for Laboratory employees include the following:

- A child development center on-site
- Flexible spending accounts (pretax dollars for medical and other expenses)
- Elective long-term elder care
- An employee assistance program (including counseling for single parents)
- Scholarships for children of Argonne employees

4. "The Pipeline"

Argonne management is aware that the Laboratory's long-term future depends on the science and engineering students of today, who increasingly must be drawn from female and minority populations. Accordingly, the Laboratory takes an active role in nurturing the widest possible future pool of scientists and engineers. For example, Argonne actively participates in programs such as Graduate Degrees for Minorities and Women in the Physical Sciences. The Laboratory also provides research participation activities for precollege students and teachers and a wide range of outreach activities throughout the Chicago area. (See Section VI.B, "Support of Science and Math Education," for a fuller discussion of many of these programs.)

The Laboratory offers remedial job training and work-study programs (such as English as a second language) and training in the area of environment, safety, and health. The basic reading and "Reading to Get Ahead" programs especially target promotion of custodians and laborers. Specific on-the-job trainee programs in areas such as waste management and maintenance also help employees graduate into more skilled positions.

The Laboratory has a high school student aide program aimed at students interested in improving their secretarial and technical typing skills. The program has been a good source of candidates for secretarial and clerical positions. Recruitment of minority students has been emphasized.

5. Five-Year Goals

Argonne has established goals for placements (i.e., numbers of hires and promotions outside of formal lines of progression) reflecting availability for job groups that are underutilized by the Laboratory as a whole. It also establishes placement goals for individual divisions where underutilization occurs.

The Laboratory circulates quarterly a booklet titled *Target Recruitment*, containing condensed resumes of women and minority candidates. To increase the flow in the relevant pipeline, the Laboratory maintains a predoctoral program emphasizing the recruitment of women and minorities. Courtesy interviews are given to qualified candidates from underutilized groups in order to increase their visibility; a formal data bank assists in identifying Hispanic candidates. In addition, the Laboratory uses techniques such as targeted advertisement and minority search firms.

The Laboratory conducts workshops to reinforce its policy against sexual harassment in the workplace.

Argonne's director is strongly committed to cultural diversity. This commitment is reinforced throughout the Laboratory by educational programs for management and employees.

The Laboratory will maintain its emphasis on helping employees balance work and family responsibilities through flexible hours and schedules and family and medical leave programs.

Argonne has coordinated the development of initiatives in support of affirmative action and equal employment opportunity among the five DOE-Energy Research multiprogram laboratories. Top management staff from the five laboratories have joined to form the Coordinating Committee on Cultural Diversity, with the primary objective of increasing the number of minorities and women in the pipeline.

IX. Environment, Safety, and Health

A. ES&H Goals and Objectives

The Department of Energy has strongly emphasized programs in the area of environment, safety, and health (ES&H) during the past several years. Argonne has responded by continuing to reinforce ES&H as a Laboratory priority.

An important Argonne objective is to monitor progress toward excellence in ES&H, by using pertinent ES&H indicators in addition to evaluations and assessments by DOE and regulatory agencies. Line management, assisted by central support and oversight organizations, conducts frequent workplace monitoring, surveillance, and evaluation to assess the design and implementation of safety practices and procedures. Safety goals are generally set above the performance levels achieved by other DOE contractors.

Argonne's ES&H programs have been developed through a commitment by management and ultimately a commitment by all Laboratory employees to excellence in ES&H, total quality management, and continuous improvement.

B. ES&H Policies, Organization, and Management

The University of Chicago maintains a Board of Governors for Argonne National Laboratory. This Board has established the policy that gives primacy to safety and protection of the environment in the conduct of operations at the Laboratory.

Argonne's safety and environmental protection policies build on the Board's stated policy that the Laboratory's activities will be conducted in a manner that gives worker and public safety and protection of the environment the highest priority. The Laboratory is committed to complying with all applicable federal and state laws, regulations, and orders regarding ES&H.

The Board of Governors carries out its oversight responsibilities through several standing committees organized along functional lines. Since 1988, the Safety and Environment Committee has been responsible for evaluating the implementation of the formal Board policy on ES&H. This committee reports to the full Board of Governors.

Argonne's director carries out his responsibilities through a management structure that includes a chief operations officer, four associate laboratory directors, and a director for ES&H and quality assurance (ES&H/QA) oversight. The four associate laboratory directors oversee Argonne's research activities. Because Laboratory policy emphasizes that safety and environmental protection are line management responsibilities, each associate laboratory director is held directly responsible for the actions of his organization in those areas.

Safety review committees have been chartered to help Argonne's director in meeting his responsibilities for safety at the Laboratory by providing independent reviews, advice, and recommendations regarding operational safety. The Laboratory's Accelerator Safety Review Committee and its Nuclear Facility Safety Committee provide extensive reviews of safety at the indicated facilities.

The chief operations officer is responsible for ES&H surveillance and technical support to the organizations at Argonne-East through the Environment, Safety, and Health Division and

Environmental Management Operations. The Environment, Safety, and Health Division has staff trained in radiation safety, fire protection, industrial and occupational safety, industrial hygiene, and emergency preparedness. Environmental Management Operations provides services in the areas of environmental remediation; environmental monitoring, surveillance, and compliance; pollution prevention; and waste management.

The deputy associate laboratory director for Argonne-West and facility operations is responsible for daily operations at Argonne's Idaho site. Surveillance and technical support to the organizations at Argonne-West are provided by two departments: (1) Environment and Waste Management and (2) Radiation, Fire, and Safety. They have staff trained in environmental protection, waste management, health physics, industrial hygiene, safety, and fire protection.

The director for ES&H/QA oversight is responsible for developing ES&H/QA policy and strategic planning, managing the Laboratory's oversight organization, reporting ES&H/QA issues to Laboratory management, coordinating with the laboratory director's review committees, coordinating the Laboratory's self-assessment program, and interfacing with the University of Chicago Board of Governors Safety and Environment Committee.

Argonne's ES&H/QA Oversight Directorate serves as a forum for identifying ES&H/QA issues. It includes members expert in ES&H disciplines and representatives from programmatic and support organizations at the Laboratory. The directorate advises the director for ES&H/QA oversight, and thereby Laboratory management, on the development of strategies, policies, and practices in the area of ES&H/QA; ensures that input from programmatic and operational organizations is appropriately considered in this development process; and ensures that strategies, policies, and practices are effectively communicated to the Laboratory population.

C. ES&H Plans and Initiatives

Argonne's *ES&H Management Plan* identifies the programs and resources needed for continued success in the Laboratory's safety and health programs. Table IX.1 summarizes funding needs identified in Argonne's current plan.

Table IX.1 Safety and Health Plan Funding for Argonne-East and Argonne-West[a]
($ in millions BA)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
Argonne-East							
Operating	20.0	21.2	21.9	23.2	24.5	25.8	27.2
Capital Equipment	0.4	0.7	0.7	0.5	0.5	0.6	0.6
General Plant Projects	1.7	1.4	2.1	1.8	1.9	2.0	2.1
Line Items	4.7	2.4	6.0	0.5	2.3	3.7	4.7
Total	26.8	25.7	30.7	26.0	29.2	32.1	34.6
Argonne-West							
Operating	10.2	11.5	11.3	11.6	12.5	12.4	13.0
Capital Equipment	-	0.3	0.5	-	-	-	-
General Plant Projects	-	-	0.2	-	0.5	0.4	0.2
Line Items	-	-	-	-	-	-	-
Total	10.2	11.8	12.0	11.6	13.0	12.8	13.2

[a]Based on the FY98 DOE *Environment, Safety and Health Management Plans*. Includes environmental activities supported with indirect funds and with direct programmatic funding, primarily from DOE-Energy Research.

1. Recent Accomplishments

In pursuit of continual improvement of its safety program, Argonne has contracted with the DuPont Safety and Environmental Management Services Group to benchmark the Laboratory to the "best in class." Eighty Laboratory managers and supervisors have

received training from DuPont on safety management techniques. Additional training and recalibration are scheduled. In FY 1995 Argonne's lost workday case rate decreased by 45%.

Argonne has implemented a chemical management system in nearly all of its divisions. Full implementation is expected by the end of FY 1996. The system is linked to the Laboratory's automated systems for materials purchasing and materials ordering, so that purchase documents automatically generate inventory records. The system also links each chemical product with a data sheet describing its properties, safe handling, and proper disposal. The system provides access to 20,000 documents around the clock at both Argonne sites and generally prevents substantial duplication of effort.

Argonne's strong total quality management initiative created a process improvement team that has identified major opportunities for simplifying the Laboratory's NEPA (National Environmental Policy Act) compliance processes. Both DOE and Argonne management support the team's recommendations and are in the process of implementing them. Consistent with the Laboratory's initiative to clarify line management's responsibility for environmental protection, safety, and quality, "NEPA owners" have been appointed for each associate laboratory director's organization and for the chief operations office. At Argonne-East, the NEPA owner serves as the primary contact between his or her organization and the site environmental compliance officer as regards NEPA-related issues of awareness, training, and guidance.

The NEPA owners are responsible for ensuring that (1) personnel within their respective organizations become familiar with the Laboratory's NEPA process, (2) NEPA procedures are incorporated into early project planning, (3) projects have the appropriate review and documentation, and (4) projects are conducted as described in project planning documents.

Argonne's total quality management initiative also created a working group — involving the DOE Chicago Operations Office and the Argonne Group within that office — to review the emergency management program for the Argonne-East site. Recommendations of the group, presented to senior management in January 1996, have already resulted in clarification of roles and elimination of significant inefficiencies.

The fire protection program at Argonne-East continues to evolve. Repair and maintenance of fire alarm systems are now performed by the Laboratory's fire protection organization, improving the effectiveness of those activities. Fire protection appraisals and automatic sprinkler system assessments are continuing, providing the critical first step toward improving the Laboratory's overall fire safety. Fire safety improvements funded as line items continue to be implemented at a rapid pace; a primary focus is life safety improvements, such as replacement of deficient fire alarm systems having inadequate evacuation signals and upgrading of exit systems. Funding of Phase IV of the Fire Safety Improvements project is critical to completing this process. Future phases addressing the remaining issues of property protection and business interruption will bring the Laboratory into compliance with industry standards.

In response to regulation 10 CFR 835 in the *Federal Register*, Argonne has submitted radiation protection program plans to DOE for review. Implementation of the Laboratory's radiological control manual has proceeded in accordance with plans. A major upgrade in the workplace air monitoring program at Argonne-East is nearing completion, having benefited from funding by DOE-Energy Research.

Argonne-East received a new NPDES (National Pollutant Discharge Elimination System) permit from the Illinois Environmental Protection Agency after submitting its applications and the required storm water characterization report. Some of the limits in the new permit are more stringent than previous limits. A recent revision to the NPDES permit established a compliance schedule that requires the Laboratory to meet the more stringent limits by July 1998. At Argonne-West, installation of a downstream monitoring well for the Snake River aquifer was completed. This well

enhances the current network of wells monitoring the aquifer.

2. Initiatives

Argonne's computerized system for identifying ES&H training requirements for employees has been revised and implemented on a new client-server platform. The questionnaire inventorying each employee's job hazards was updated, and course requirements for each employee were limited to those determined by regulation or by decision of the employee's line management. Employees spend less time away from the job under the new system.

In cooperation with Brookhaven National Laboratory, Argonne is continuing initiatives in cooperative computer-based training. This training format is reducing by 25-50% the time required for initial training and later retraining of radiation workers.

Argonne's World Wide Web home pages for information on ES&H training and other ES&H activities are becoming increasingly valuable. To be included in the near future are the Laboratory's general ES&H newsletter, its retraining manual, and the job hazards questionnaire discussed above.

Initial characterization of asbestos-containing building materials at the Argonne-East site was more than 90% complete by the end of FY 1995, with the remainder scheduled for completion by the end of FY 1996. Materials are ranked by condition and accessibility, to allow risk-based ranking for remediation. Approximately 8,600 cubic feet of asbestos-containing materials were removed from the Laboratory during CY 1995.

In accordance with the Clean Air Act Amendments, Argonne-East submitted its Title V permit application for all air emissions on September 13, 1995. The Illinois Environmental Protection Agency issued a completeness determination on October 26, 1995, indicating that the application was acceptable. The permit application for Argonne-West will be included in the application for the Idaho National Engineering Laboratory.

Argonne continues to work toward minimizing the number of its nuclear facilities and thereby reducing associated regulatory costs. Key activities in this work are source certifications, special storage applications, and disposal actions.

The Laboratory is continuing a major initiative to improve the efficiency of its ES&H activities. The overall objective is continued progress toward excellence in ES&H with lower total cost. By eliminating redundancies and other activities having low value and by implementing greater line responsibility for ES&H, Argonne has decreased staffing for technical support, surveillance, and oversight. Safety funding is being redirected to both line functions and safety upgrades. The Laboratory is also evaluating opportunities for reducing costs by outsourcing ES&H activities.

D. Environmental Management

At Argonne, DOE-Environmental Management supports environmental restoration and waste management activities that improve environmental quality, in support of DOE's core values.

Environmental restoration at Argonne-East includes remediation of areas where contamination has been found or is considered likely on the basis of historic information. In addition, reactor sites and hot-cell facilities are being decontaminated and decommissioned as part of a systematic program to deal with formerly used radiological facilities.

Waste management initiatives at Argonne-East include upgrading facilities to meet current requirements for handling and storing wastes, upgrading water treatment facilities to ensure compliance with the NPDES permit and other regulations, and implementing a waste minimization and pollution prevention program. Argonne has prepared a proposed site treatment

plan for mixed wastes required by the Federal Facilities Compliance Act.

At Argonne-West, DOE-Environmental Management supports activities defined in the Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory (INEL), in which DOE, the U.S. Environmental Protection Agency, and the state of Idaho collectively participate. This agreement establishes a procedural framework and a schedule for developing, prioritizing, implementing, and monitoring appropriate response actions at INEL, in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act; the Resource Conservation and Recovery Act (RCRA); and the Hazardous Waste Management Act.

Funding for Argonne's programmatic environmental restoration and waste management activities is summarized in Table IX.2.

1. Recent Accomplishments

Argonne completed several key environmental management projects in FY 1995.

a. Cleanup of Potential Release Sites

In the 317/319/east-northeast area at Argonne-East, a test pit investigation was completed, field work began for the RCRA facility investigation, the south vaults were cleaned and demolished, and an interim leachate collection trench was installed (in the 319 area). Field work began for the RCRA facility investigation in the 800 area. Approximately 5,000 cubic yards of lime sludge were removed from Argonne-East and applied to farmland as a soil sweetener. Phase I of the site-wide hydrogeologic assessment was completed, and 31 unused or unusable wells and boreholes were closed. Information was provided to the Illinois Environmental Protection Agency to recommend no further action on a large number of solid waste management units, reducing their current number to 71. Work toward further reductions continues. Sludge contaminated with polychlorinated biphenyls was removed from the Laboratory's wastewater treatment plant and placed in containers pending permanent disposal. Decontamination and decommissioning of the Experimental Boiling Water Reactor was completed, and conversion of the reactor building for future storage of transuranic waste began. Cleanup of the hot cells in Building 200 was completed, eliminating associated release of radon-220. Glove boxes in Building 212 were decontaminated and are now awaiting shipment off-site.

b. Waste Management

Argonne-East has shipped off-site for disposal or storage a substantial quantity of radioactive waste accumulated in the past, significantly reducing the Laboratory's inventory. A new evaporator-concentrator was installed in Building 306 to reduce volumes of waste liquids more efficiently.

c. Acceleration of Remedial Investigation and Feasibility Study

The U.S. Environmental Protection Agency, the state of Idaho, and DOE agreed on a conceptual schedule for accelerating the comprehensive remedial investigation and feasibility study for Waste Area Group 9. The approach agreed upon will significantly reduce cost and duration.

2. Initiatives

In support of the strategic goals of DOE-Environmental Management, Argonne is undertaking three major initiatives.

a. Improvement of Water Systems

The construction contract for the Laboratory Wastewater Treatment Plant was awarded on January 19, 1996. Construction is proceeding, with a scheduled completion date of December 31, 1996. Plant commissioning activities are scheduled to begin in January

Table IX.2 Environmental Restoration and Waste Management Programs: Funding Requirements for Argonne-East and Argonne-West[a] ($ in millions BA; personnel in FTE)

	FY96	FY97	FY98	FY99	FY00	FY01	FY02
ARGONNE-EAST							
Environmental Restoration							
Operating	9.0	9.3	9.3	9.3	9.3	9.3	9.3
Capital Equipment	-	-	-	-	-	-	-
General Plant Projects	-	-	-	-	-	-	-
Line Items	-	-	-	-	-	-	-
Total	9.0	9.3	9.3	9.3	9.3	9.3	9.3
Direct Personnel	39.0	39.0	39.0	39.0	39.0	39.0	39.0
Waste Management							
Operating	11.1	8.6	7.6	7.6	7.6	7.6	7.6
Capital Equipment	0.3	-	-	-	-	-	-
General Plant Projects	-	-	-	-	-	-	-
Line Items	-	1.1	-	-	-	-	-
Total	11.4	9.7	7.6	7.6	7.6	7.6	7.6
Direct Personnel	53.0	48.0	45.0	45.0	45.0	45.0	45.0
Grand Total							
Operating	20.1	20.4	20.4	20.4	20.4	20.4	20.4
Capital Equipment	0.3	0.1	0.1	0.1	0.1	0.1	0.1
General Plant Projects	-	-	-	-	-	-	-
Line Items	-	-	-	-	-	-	-
Total	20.4	20.5	20.5	20.5	20.5	20.5	20.5
Direct Personnel	92.0	92.0	92.0	92.0	92.0	92.0	92.0
ARGONNE-WEST							
Environmental Restoration							
Operating	2.0	1.7	2.0	2.0	2.0	0.9	0.4
Capital Equipment	-	-	-	-	-	-	-
General Plant Projects	-	-	-	-	-	-	-
Line Items	-	-	-	-	-	-	-
Total	2.0	1.7	2.0	2.0	2.0	0.9	0.4
Direct Personnel	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Waste Management							
Operating	3.2	5.2	3.2	3.3	3.2	3.2	3.2
Capital Equipment	-	-	-	-	-	-	-
General Plant Projects	0.4	0.3	0.3	0.1	0.3	0.3	0.3
Line Items	-	-	-	-	-	-	-
Total	3.6	5.5	3.5	3.4	3.5	3.5	3.5
Direct Personnel	8.5	23.5	8.5	8.5	6.5	6.5	6.5
Grand Total							
Operating	5.2	6.9	5.2	5.3	5.2	4.1	3.6
Capital Equipment	-	-	-	-	-	-	-
General Plant Projects	0.4	0.3	0.3	0.1	0.3	0.3	0.3
Line Items	-	-	-	-	-	-	-
Total	5.6	7.2	5.5	5.4	5.5	4.4	3.9
Direct Personnel	11.5	13.5	15.0	13.5	11.5	11.5	11.5

[a]This table reflects DOE guidance for Argonne's FY97 Activity Data Sheets — Funding for On-Site Remediation and Waste Management. (Compare with Table XII.10, which combines Argonne-East and Argonne-West and includes other funding from DOE-Environmental Management.)

1997, and a fully functional facility is expected to be operational by June 1997.

b. Enhancement of Waste Management Facilities

Phase I of the rehabilitation of Building 306 was completed in January 1996, providing additional, improved facilities for waste management operations. As noted above, work to convert the Experimental Boiling Water Reactor to a transuranic waste storage facility has begun. Construction of a storage facility for mixed waste is also progressing.

c. Field Characterization for Waste Area Group 9

At Argonne-West, the Laboratory is performing field characterization for environmental cleanup in operational units 9-01, 9-03, and 9-04. This field characterization is the first major activity aimed at improving the speed and cost of the remedial investigation and feasibility study for Waste Area Group 9.

X. Site and Facilities

A. Laboratory Description

1. Overview of Site and Facilities

Argonne National Laboratory conducts basic and technology-directed research at two sites owned by the U.S. Department of Energy (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 Laboratory, 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 Intense Pulsed Neutron Source, the Argonne Tandem-Linac Accelerator System, and the High Voltage Electron Microscope. All these facilities are heavily used by researchers from outside Argonne, as described in Chapters V and VI. The Alpha-Gamma Hot Cell Facility supports examinations of materials for major Laboratory programs. Construction of the Advanced Photon Source (APS), which will be the Laboratory's largest user facility, will be completed in 1996. Argonne-East also houses a full spectrum of administrative and technical support organizations, as well as the DOE Chicago Operations Office and the New Brunswick Laboratory, both of which use facilities operated and maintained by Argonne.

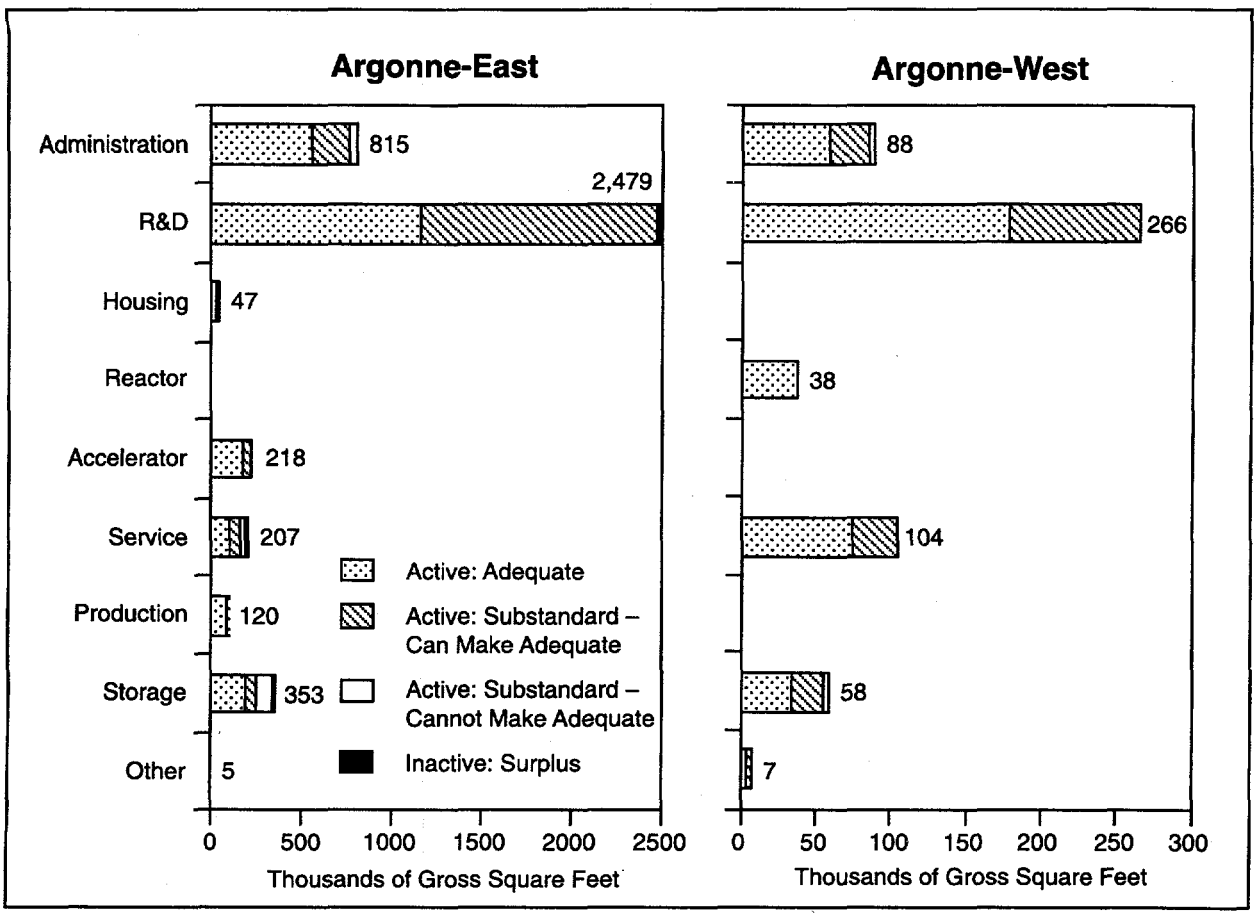
Programs for the DOE Office of Energy Research account for over half of the space usage at Argonne-East. Figure X.1 summarizes the distribution of space at Argonne-East (and Argonne-West) by *functional unit* (administrative, housing, R&D, and so on) and by condition of space, as a percentage of gross square footage.

Altogether, Argonne-East houses roughly 5,700 persons, of whom about 3,400 are regular Argonne employees. The Argonne-East site includes 107 buildings having 4.2 million total square feet of floor space. Most were built during the 1950s and early 1960s. The Laboratory is also leasing 94,000 square feet of office space in a commercial park near the Argonne-East site to alleviate a temporary space shortage. (See Table X.1, which includes small additional amounts of space leased off-site.) Figure X.2 summarizes the ages of Argonne-East (and Argonne-West) facilities. The replacement value of existing facilities at Argonne-East is estimated to be $1.52 billion. (See Table X.2; the value is expected to be approximately $0.35 billion higher at the end of FY 1996 as a result of completing capitalization of the APS.)

Adequate land area is available to accommodate Argonne's plans for expansions of programs in basic research and other areas. Site infrastructure generally can accommodate modest growth, provided that support systems are maintained or upgraded to meet current standards for environmental protection, safety, and reliability. Facilities are now almost fully occupied, so additional construction will be required to satisfy growing programs and to continue the planned removal of obsolete and deteriorated facilities.

b. Argonne-West

Argonne-West conducts R&D and operates facilities for DOE. With termination of the Integral Fast Reactor program in FY 1994, the



	Space at Argonne-East				Space at Argonne-West		
	Active				Active		
		Substandard				Substandard	
	Adequate	Can Make Adequate	Cannot Make Adequate	Inactive (Surplus)	Adequate	Can Make Adequate	Cannot Make Adequate
Administration	565	198	43	9	58	28	2
R&D	1,162	1,307	10	0	178	88	0
Housing	35	12	0	0	0	0	0
Reactor[a]	0	0	0	0	38	0	0
Accelerator	177	41	0	0	0	0	0
Service	108	53	30	16	74	30	0
Production	86	29	5	0	0	0	0
Storage	186	57	101	9	34	21	3
Other	0	5	0	0	5	2	0
TOTAL[b]	2,320	1,700	188	34	387	169	5

[a]The reactor building at Argonne-West and some support facilities are being prepared for shutdown activities.

[b]Totals and column entries were rounded independently.

Figure X.1 Distribution of space at Argonne-East and Argonne-West in 1996 by function and condition.

Table X.1 Argonne-East Space Distribution

Location	Area (thousands of square feet)
Main Site	4,243
Leased Off-Site	126
Total	4,369

programmatic mission of the Argonne-West facilities changed significantly. As discussed in Section V.A.1, current research focuses are (1) use of electrometallurgical techniques to condition the driver and blanket assemblies from the Experimental Breeder Reactor-II (EBR-II), (2) reactor and fuel cycle safety, and (3) decontamination and decommissioning (D&D) technology. In addition to Nuclear Energy, Science and Technology, DOE programs using Argonne-West facilities include (1) Nonproliferation and National Security and (2) Environmental Management.

The Waste Characterization Area (WCA) within the Hot Fuel Examination Facility (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. In conjunction with the Gas Generation Project, a glove box operation in the Zero Power Physics Reactor (ZPPR) facility, the WCA will allow monitoring of potential gas buildup in waste packages bound for the WIPP.

The ZPPR, now shut down, 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 basis for efforts to help the former Soviet Union with nonproliferation technology.

The main cell of the 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 disassemble spent fuel from the EBR-II and place the fuel elements or pins into containers for temporary storage. The HFEF is an extremely versatile facility suitable for work such as nondestructive or destructive examination of radioactive materials and development of spent-fuel waste forms, as well as other kinds of work requiring remote handling of radioactive materials.

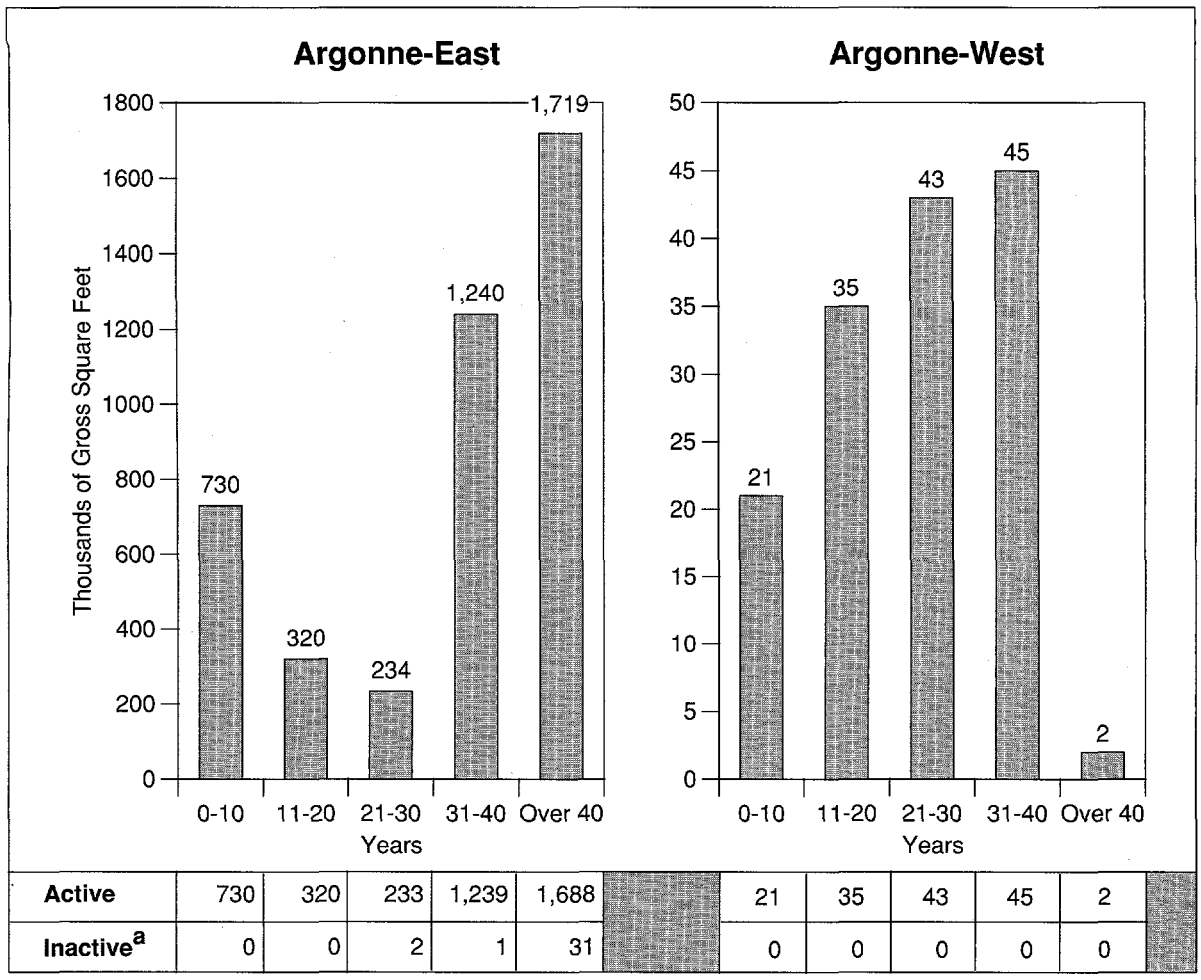
The EBR-II is now shut down and is in the process of being defueled. It is serving as a demonstration facility for the development of D&D methods for nuclear plants. A key technological issue is treating EBR-II spent fuel to stabilize it from a mixed hazardous waste to a final form that will meet the requirements of a geologic repository. This problem will be addressed at the Fuel Conditioning Facility (FCF), where sodium will be removed from inside the EBR-II fuel, and the spent fuel will be converted from a mixed hazardous waste to a stable metallic and mineral waste form.

The Sodium Processing Facility treats sodium from the EBR-II and other sources, converting elemental sodium first to sodium hydroxide and then to sodium carbonate for ultimate disposal. Technology from the facility could be adapted to sodium processing for the Fast Flux Test Facility.

The Transient Reactor Test Facility (TREAT) is not operating, but the facility is hosting the Plasma Hearth Project, which is testing a means of using a plasma arc torch to turn low-level waste into a stable, glass-like substance. The torch melts both the waste container and its contents, converting them into a highly stable form for disposal.

The Fuel Manufacturing Facility (FMF), previously used to fabricate fuel for the EBR-II, is now manufacturing dummy stainless steel subassemblies for replacement purposes in the defueling of the EBR-II. The FMF has glove boxes and a storage vault for special nuclear materials.

Supporting the major facilities at Argonne-West is an array of shops, warehouses, laboratories (including a newly refurbished analytical chemistry laboratory), offices, and utility systems.



	Argonne-East					Argonne-West				
	0-10	11-20	21-30	31-40	Over 40	0-10	11-20	21-30	31-40	Over 40
Active	730	320	233	1,239	1,688	21	35	43	45	2
Inactive[a]	0	0	2	1	31	0	0	0	0	0

[a]Inactive space is too small to be displayed graphically. Entries were rounded independently.

Figure X.2 Age of Laboratory buildings at Argonne-East and Argonne-West in 1996.

Table X.2 Replacement Value of Argonne Facilities (millions of FY 1995 dollars)

Facilities Types	Argonne-East	Argonne-West
Buildings	966	170
Utilities	118	23
All Others	431	159
Total	1,516[a]	352

[a]Completion of the capitalization process for the Advanced Photon Source project by the end of FY 1996 is expected to increase the total value of Argonne-East facilities by approximately $350 million.

Argonne-West houses about 760 employees. The site has 52 buildings with 600,000 gross square feet of floor space. Most of the buildings and other infrastructure were built during the mid to late 1960s. Figure X.2 summarizes the ages of Argonne-West facilities. Replacement value of existing facilities at Argonne-West is estimated to be $352 million. (See Table X.2.)

2. Status of Existing Facilities and Infrastructure

Because most building and facility infrastructure systems have a 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 backlog 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 and 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 objectives of the management of site and facilities at Argonne-East are to improve use of facilities, eliminate substandard facilities, and upgrade strategic facilities and systems. Demolition of substandard buildings has reduced both energy costs and operating and maintenance expenses. These actions have eliminated many unsightly areas, and cleared sites have been restored and made available for future Laboratory facilities. Upgrading through the ongoing In-House Energy Management program has included improvements in energy efficiency that have helped to reduce the Laboratory's bills for fuel and electricity.

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. The other main thrust of the facilities management program involves upgrading or revitalizing strategic buildings, utility systems, and other infrastructure. Included are modifications of existing facilities to accommodate new initiatives; to increase safety, health, and environmental acceptability; to save energy; and to replace obsolete building systems that require excessive maintenance. Part of this work has already been completed, and some is currently in progress. However, much more is needed. Preliminary planning has been completed for remaining upgrading needs. The DOE Chicago Operations Office and DOE Headquarters have been closely involved in the upgrading program since its inception and have actively supported it. The rehabilitation program would not have been possible without strong endorsement and funding from the DOE Multiprogram Energy Laboratories — Facilities Support (MEL-FS) program and its predecessors.

The principal challenges facing Argonne-East today still stem from the normal aging of buildings and infrastructure and the resulting substantial needs for updating. Some substandard facilities require replacement. In addition, some facilities require D&D or modifications to meet changing program needs or new environmental regulations. As part of DOE's Surplus Facilities Inventory and Assessment program, initiated in October 1993, Argonne-East has completed a comprehensive review and assessment of site facilities, aimed at identifying those appropriate for inclusion in programs of DOE-Environmental Management. Existing space is over 99% utilized. Figures X.1 and X.2 summarize the condition and age, respectively, of facilities at Argonne-East (and Argonne-West). Overall, utility systems are adequate for anticipated needs. Selected aspects of several utilities require upgrades for compliance with standards and increased reliability. Major rehabilitation of the central steam plant, funded in FY 1995, is underway. Argonne's stated goal for future waste discharges is full compliance with applicable standards and regulations. The Laboratory is pursuing the purchase of municipal water from adjacent communities as an alternative to continued reliance solely on obsolescing wells on-site. Connection with the municipal pipeline is anticipated in FY 1996. Use of municipal water will contribute to the Laboratory's continued compliance with discharge permit regulations.

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 at least 15 more years. 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, but a backlog of needed repairs and rehabilitation that will cost several million dollars has accumulated. Figures X.1 and X.2 summarize the condition and age, respectively, of facilities at Argonne-West.

The analytical laboratory now operating at Argonne-West has been upgraded to meet the key roles it plays in activities at the site. Originally built in the late 1950s, many of its components and systems were recently replaced. To meet today's requirements for handling plutonium-bearing fuels, a new ventilation system was installed, hot cell windows were refurbished, and new remote manipulators were purchased.

B. Facilities Plans and Options

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 major long-range objective of Argonne's site and facilities planning is preservation of the Laboratory's substantial investment in capital facilities while meeting technical and programmatic needs. Long-range facilities planning remains flexible and is updated to accommodate changing missions and directives.

1. Argonne-East

On the basis of current programmatic planning, the major changes at Argonne-East over the next 10-15 years will include expansion of programs in basic research and industrial technology. Long-range development plans for Argonne-East provide for the Laboratory and programmatic initiatives described in Chapters IV and V, while the needs of existing programs are met.

Planning and construction of the APS have exemplified the effectiveness of the Laboratory's long-range planning. Land in the 400 area used for APS construction has access to all site services. Existing utilities have sufficient capacity for both the APS and its associated initiatives without disrupting current activities.

Staffing of the APS during its construction, along with expansion of other programs, caused a space shortage at the main Argonne-East site. To meet this need, the Laboratory leases 94,000 square feet of off-site space and has also been using 64 office trailers on the Illinois site (33,000 square feet of which are leased). Space recently vacated by APS activities is being used first to reduce the number of trailers and to relieve dependence on unreliable, substandard "temporary" buildings. In all, 42,000 square feet of substandard space will be demolished, and an additional 43,000 square feet of trailers will be removed in the near future.

The APS project achieved initial beneficial occupancy of the LINAC injection wing in FY 1992. In early FY 1993, beneficial occupancy of the assembly area of the experiment hall and the utility building was achieved. FY 1996 will see full beneficial occupancy of the balance of the complex. The state of Illinois has provided $18.9 million for the design and construction of a 240-bed user residence facility on the APS site, within walking distance of the experiment hall. Construction began in FY 1995 and is expected to be completed in FY 1996.

The Laboratory remains strongly committed to collaborative research and technology transfer. Long-range site planning includes land in the east area dedicated to construction of a technology transfer center. Modifications,

upgrades, or expansion of existing facilities will also be undertaken as required to accommodate other scientific initiatives.

The Laboratory is continuing its initiative to replace deteriorated, substandard structures (Figure X.3). A new transportation and grounds facility in the east area, completed in 1994, permitted the demolition of several substandard buildings located in the west area. Additional plans call for a new central supply facility and a permanent centralized facility to house various site support groups. Long-range site planning calls for these buildings to be located in the dedicated service area in the east area of the site.

Argonne-East has also developed plans to upgrade, as funding allows, permanent laboratory and office facilities; electrical, steam, and chilled water systems; roads and sidewalks; and the central heating plant. The Laboratory is developing facilities to allow utilization of an outside water supply, because the quality of the water it now obtains from wells is deteriorating.

The Laboratory has also developed plans for D&D of facilities no longer in use, ensuring removal or containment of potential environmental hazards and allowing reuse of the land or facilities. The Laboratory's plans for D&D of inactive surplus facilities are discussed in Section X.D.

Environmental activities command the highest priority at Argonne. (See Chapter IX.) At Argonne-East, these activities 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. Environmental projects that are planned or underway are discussed in Chapter IX.

Energy efficiency and conservation are also strong priorities at Argonne. The Laboratory is conducting detailed studies of its energy usage and is retrofitting facilities as required. Planning has begun for construction of a cogeneration facility at Argonne-East under an energy savings performance contract. The Laboratory is

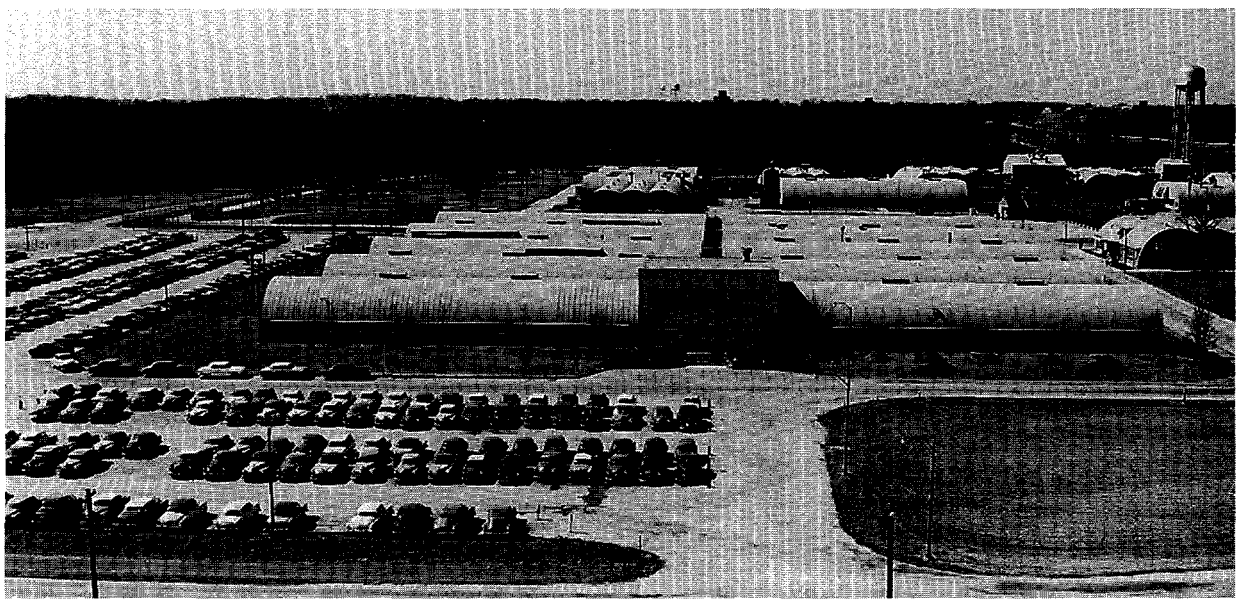


Figure X.3 Removal of the facilities pictured in this historical photograph, after they became obsolete and deteriorated, has reduced utility and maintenance expenses, mitigated environmental liabilities, and readied portions of the Argonne-East site for future missions and innovative reuse.

also benefiting from participation in the demand-side load management program of its electric utility, Commonwealth Edison.

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. Recent projects have renovated many public areas, improved landscaping and parking areas, and generally enhanced the site's appearance to reflect its status as a world-class research facility.

Along with rehabilitation, demolition, D&D, and site enhancement, maintenance of facilities at Argonne-East continues to receive high priority. This ongoing process improves productivity, increases efficiency, and generally directs resources to their most effective applications. Argonne inspects its facilities through a formal Condition Assessment Survey process. The Laboratory maintains a management information system for work requests and processing of backlog information in order to better integrate implementation of tasks and use of resources.

2. Argonne-West

The mission of Argonne-West is part of the Laboratory's overall mission in nuclear technology, which has two major elements (see Section III.D.3.b and Section V.A.1). The first major element is termination of the Integral Fast Reactor program and associated activities, including shutting down the EBR-II. The second major element is a redirected program addressing issues such as the treatment of spent nuclear fuel, reactor and fuel cycle safety, and development of technologies for the D&D of reactors and other nuclear facilities.

Environmental activities command high priority at Argonne. (See Chapter IX.) The objective of Argonne-West's environmental program is to ensure that the Laboratory has no adverse effect on the environment and complies with existing environmental regulations. Major activities include (1) replacing transformers containing polychlorinated biphenyls; (2) sampling and analyzing past releases of hazardous materials into ponds, ditches, and other areas; (3) replacing underground storage tanks; (4) upgrading the radioactive storage waste facility; and (5) seeking permits from the U.S. Environmental Protection Agency and the state of Idaho for certain ongoing activities.

After the upgrading of Argonne-West's fire protection system was about half completed, funding for completion of the program was withdrawn. To date, about $3.4 million has been committed to improving fire protection for major facilities. Another $4.2 million is needed to correct deficiencies in other important support facilities. Other higher priority plans for correcting deficiencies at the site address roofing and insulation, roads, storm drainage, water supply isolation valves, deep-well pumps, electrical duct banks and feeders, steam and condensate lines, communications systems, and radioactive-liquid-waste lines. Lightning protection will be extended. The general aims of these rehabilitation plans are to avert troublesome and expensive failures and to comply more closely with DOE criteria for general purpose facilities.

C. General Purpose Facility Plans

Argonne's planning for general purpose facilities focuses on maintaining facilities that are both safe and efficient.

1. Argonne-East

At Argonne-East the main issues for general purpose facilities are substandard facilities and infrastructures and shortages of space. New facilities are currently planned to serve the following functions: central supply, central support, multiprogram laboratories and offices, and technology transfer. This construction will allow demolition of several substandard facilities remaining on the site after current consolidation of space usage is complete.

Argonne-East is also proposing to upgrade a number of facilities to meet fire and electrical safety requirements. Other planned upgrades address electrical services; steam distribution and mechanical systems; and various roads, sidewalks, and parking areas. General plant projects (GPP) to eliminate deficiencies in facilities largely fall into three general categories: safety and environmental compliance, infrastructure upgrades, and facility upgrades. Because of inadequate funding in prior years, the backlog of GPP work at Argonne-East has grown to tens of millions of dollars. (GPP funding for FY 1985-FY 1995 averaged less than $2.5 million per year.)

The GPP backlog problem is compounded by the aging of Argonne-East facilities. Excluding the APS project, over 48% of the floor space at the site is now more than 40 years old. Approximately 5% of this space needs to be replaced, and another 40% needs upgrading. The Laboratory is requesting additional funding to reduce its GPP backlog.

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. Planned or under construction are new facilities for programmatic support, including environmental activities, waste handling, and related efforts. Correction of facility-related deficiencies is a planning focus.

D. Inactive Surplus Facilities Plan

1. Argonne-East

Argonne-East has developed a program and assembled a skilled team for timely D&D of facilities no longer in use, ensuring appropriate removal or containment of potential environmental hazards and allowing reuse of facilities where warranted. The program is funded by DOE-Environmental Management.

Three major D&D projects were recently completed. Work at the Experimental Boiling Water Reactor was completed; the building is being converted to a transuranic storage facility. More than 60 contaminated surplus glove boxes in Building 212 were downsized and sent to Hanford for burial. The offices and laboratories in the area containing the glove boxes are now available for general use. Five of the hot cells in the M-Wing of Building 200 were decontaminated sufficiently that radon releases — previously the largest source of off-site exposure — were reduced by more than 95%. The cells now will be available for future programs. D&D of the CP-5 Reactor is continuing and will be completed in 1999. Characterization of the JANUS Reactor has been completed, and field work will begin later this year. Identified for future D&D are the Argonne Thermal Source Reactor (Building 315), the Zero Power Reactors 6 and 9 (Building 316), the Juggernaut Reactor, the 60-Inch Cyclotron, the Fast Neutron Generator (Building 314), the Waste Ion Exchange Facility (Building 579), and surplus retention tanks (Building 310).

More than half of the D&D work identified for the Argonne-East site has been completed. DOE and Argonne are now pursuing a Small Sites Initiative Program, through which remaining D&D work will be completed in less than five years at a cost of approximately $40 million.

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, while demolition of 67 substandard buildings and removal of 19 temporary trailers eliminated roughly twice as much building space, resulting in a net loss of 270,000 gross square feet or about 7% of the Laboratory total. Argonne's plans call for continued removal and clearing of the old east and 800 areas of the site. By the end of 1996, Argonne-East will have further eliminated nearly 42,000 square feet of buildings and 43,000 square feet of trailers. However, future progress depends on continuing

receipt of line-item funding to construct suitable replacement space.

2. Argonne-West

All facilities at Argonne-West are being actively used, including EBR-II facilities, which, in addition to supporting defueling activities, are providing power switching, site monitoring, cooling water, compressed air, and other services.

E. Facilities Resource Requirements

Table X.3 (presented at the end of this section) describes all facility projects for which capital funds have been appropriated or requested, or that will be proposed in the near future. The projects fall into three broad categories: (1) direct support for specific programmatic objectives, (2) environmental remediation, and (3) rehabilitation of the physical plant. The last category includes GPP and multiprogram general purpose facility projects. Construction funds required for programmatic initiatives are discussed in Chapters IV and V.

1. Argonne-East

Funding for upgrading or replacing substandard facilities at Argonne-East has generally been provided through the MEL-FS program. Continuation of the current sitewide revitalization will require continued funding. Line-item funding through the MEL-FS program and its predecessors has allowed the Laboratory to replace or rehabilitate major portions of the on-site infrastructure and the most severely deteriorated facilities. Construction of new facilities under the MEL-FS program, along with rehabilitation of existing space, has allowed the Laboratory to consolidate roughly 60% of the site population into the 200 area.

Additional MEL-FS funding is needed to further rehabilitate building systems in permanent office and laboratory buildings; to upgrade various utility systems, especially those critical to continued environmental safety; and to provide suitable space for support activities.

A small number of substandard structures remain in use. Most seriously deteriorated are facilities located in the 800 area, the majority of which will be demolished in FY 1996 as part of a site consolidation program, and supply facilities located in the east area. These facilities are to be replaced by a new central supply facility being proposed for FY 1998 funding. Future MEL-FS funding will also be needed to replace other remaining substandard structures with new facilities that use less energy and are generally more efficient to operate.

Appropriate levels of GPP funding are essential to the continued vitality and efficiency of Laboratory programs and for operation of the Laboratory in a safe and environmentally acceptable manner. Plans call for GPP funds to be used to modify, replace, or upgrade existing facilities and to correct deficiencies related to environment, health, and safety. Increased GPP funding will be needed if the Laboratory is to continue to address environmental, health, and safety demands while meeting facility needs as they arise. Adequate GPP funding will prevent premature deterioration or failure of facilities and systems resulting from deferred maintenance or repairs and will ensure compliance with existing and new environmental regulations and permits.

2. Argonne-West

As facilities at Argonne-West age, a high priority is progress each year toward replacement and refurbishment of various facility systems. The annual expense of upgrading all facilities to "new" condition would be about $11 million. Normal maintenance, repair, and upgrade costs of about $2 million are needed annually to keep facilities functional and to stay abreast of escalating mandatory requirements in areas such as safety and environmental

compliance. In FY 1996, Argonne-West received no GPP funds.

The GPP funding requirements at Argonne-West 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 environmental, safety, and health regulations and permits.

F. Asset Management

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 mission, ecologic, economic, cultural, and social factors; considers the site's larger regional context; and involves stakeholder participation.

Argonne's assets are acquired, rehabilitated, and upgraded to support the Laboratory's mission. Real estate acquisitions are executed by DOE through a Department-certified real estate specialist. All modifications and improvements are designed and constructed in compliance with appropriate 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 DOE corporate physical assets database (the Facilities Information Management System) contains a current inventory of the Laboratory's physical assets. Periodically, this inventory is systematically reviewed, and the condition of the assets is assessed. To keep its assets functioning effectively, Argonne determines maintenance requirements and budgets. The Laboratory's work management system provides for the maintenance (preventive, predictive, and corrective) required so that assets are available to serve their planned missions; the process also ensures that assets are readied for disposal when appropriate. Backlogs associated with such maintenance, 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 assured through a configuration management process.

Surplus facilities are identified through the Laboratory's planning process and are reported to DOE in a timely manner. Transference of assets between program offices is performed 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.

G. General Purpose Equipment

For Argonne to serve DOE as a premier multiprogram laboratory, its support infrastructure must include equipment allowing efficient performance. A substantial increase in funding for general purpose equipment (GPE) will be needed to meet this requirement.

The GPE funds are the Laboratory's primary basis for purchasing equipment needed to perform vital support activities such as (1) plant maintenance; (2) health and safety; (3) monitoring and control of effluents to the environment; (4) motor vehicle services; (5) technological support, including administrative computers, machine shops, electronics, 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 major new equipment needed to meet current and future requirements in a timely manner. Current annual GPE funding of approximately $2 million permits acquisition of only critically needed equipment, and little progress can be made toward systematically replacing obsolete equipment. The average age of equipment now in use in critical areas (such as plant facilities and services; environment, safety, and health; electronics; and computing) significantly exceeds DOE guidelines for life expectancy. The cost to replace fully depreciated GPE equipment in use is estimated to exceed $30 million.

To support Argonne's challenging programmatic and site-related initiatives during the next five years most effectively, substantially greater GPE funding will be needed to revitalize the Laboratory's support infrastructure. (See Table X.4; Table X.5 provides analogous information for Argonne-West.) Increases are necessary for orderly elimination of the backlog of needed GPE equipment and for timely acquisition of equipment required to provide new capabilities. The Laboratory's emphasis on supporting additional safety and environmental activities — particularly responses to self-assessments and corrective actions to meet expanding DOE, federal, and state requirements — has caused further diversion from addressing the growing backlog in other areas.

Table X.4 Projected General Purpose Equipment Funding at Argonne-East ($ in millions BA)

FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02
2.2	2.0	3.5	3.7	3.9	4.1	4.3	4.5

Table X.5 Projected General Purpose Equipment Funding at Argonne-West ($ in millions BA)

FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02
-	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table X.3 Major Construction Projects ($ in millions BA)

	TEC	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Funded Projects									
39-AF-95									
Office of Nuclear Energy, Science, and Technology									
Nuclear Energy Research and Development									
General Plant Projects, ANL-West (GP-N-102)	3.5	1.6	-	-	-	-	-	-	-
Modifications to Reactors, ANL-West (92-E-200)	1.9	1.9	-	-	-	-	-	-	-
Modifications to Reactors, ANL-West (95-E-207)	3.2	1.5	1.7	-	-	-	-	-	-
39-EX-11									
Office of Environmental Management									
Corrective Activities (Non-Defense)									
Sanitary Waste Water Treatment Plant Improvements, ANL-East (90-R-119)	8.5	-	1.2	-	-	-	-	-	-
39-EX-31									
Office of Environmental Management									
Waste Management (Non-Defense)									
Rehabilitate Waste Management Building 306, ANL-East (91-E-600)	3.2	-	0.1	-	-	-	-	-	-
Hazardous, Radioactive, and Mixed Waste Storage Facilities, ANL-East (91-E-602)	8.6	3.6	-	-	-	-	-	-	-
General Plant Projects, ANL-West (GP-E-600)	1.5	0.4	0.4	-	-	-	-	-	-
39-KB-00									
Office of Energy Research									
Nuclear Physics									
Accelerator Improvements, ANL-East (94-G-302) (95-G-302)	0.8	0.5	0.3	-	-	-	-	-	-
39-KC-02									
Office of Energy Research									
Basic Energy Sciences									
Materials Sciences									
Advanced Photon Source, ANL-East (89-R-402)	467.2	58.4	3.2	-	-	-	-	-	-

Table X.3 Major Construction Projects (Cont.)

	TEC	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Funded Projects (Cont.)									
39-KC-03									
Office of Energy Research									
Basic Energy Sciences									
Chemical Sciences									
General Plant Projects, ANL-East (GP-E-400)	6.5	2.2	4.3	-	-	-	-	-	-
39-KG-01									
Office of Energy Research									
Multiprogram Energy Laboratories —									
General Purpose Facilities									
Electrical System Upgrade - Phase II, ANL-East (93-E-313)	4.8	2.0	-	-	-	-	-	-	-
Central Heating Plant Rehabilitation - Phase I, ANL-East (95-E-301)	9.9	1.3	2.6	2.5	3.4	-	-	-	-
39-KG-02									
Office of Energy Research									
Multiprogram Energy Laboratories —									
Environment, Safety, and Health Support									
Fire Safety Improvements - Phase II, ANL-East (93-E-320)	5.4	1.5	2.4	0.2	-	-	-	-	-
Fire Safety Improvements - Phase III, ANL-East (95-E-307)	3.0	0.2	1.1	1.0	0.7	-	-	-	-
Building Electrical Service Upgrade - Phase I, ANL-East (96-E-330)	7.9	-	1.2	1.1	5.3	0.3	-	-	-
39-KP-00									
Office of Energy Research									
Biological and Environmental Research									
Structural Biology Center, ANL-East (94-E-338)	14.9	6.7	4.3	-	-	-	-	-	-
39-WB-00									
Office of Associate Deputy Secretary for Field Management									
In-House Energy Management									
Modifications for Energy Management (IH-E-500)	4.3	2.3	2.0	-	-	-	-	-	-
TOTAL FUNDED PROJECTS	555.1	84.1	24.8	4.8	9.4	0.3	0.0	0.0	0.0

Table X.3 Major Construction Projects (Cont.)

	TEC	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Budgeted Projects									
39-AF-95									
Office of Nuclear Energy, Science, and Technology									
Nuclear Energy Research and Development									
General Plant Projects, ANL-West (GP-N-102)	2.0	-	-	2.0	-	-	-	-	-
Modification to Reactors	2.2	-	-	2.2	-	-	-	-	-
39-EX-31									
Office of Environmental Management									
Waste Management (Non-Defense)									
General Plant Projects, ANL-West	0.3	-	-	0.3	-	-	-	-	-
Waste Handling Facility, ANL-West (97-CH-063)	3.2	-	-	0.4	2.8	-	-	-	-
39-KB-00									
Office of Energy Research									
Nuclear Physics									
Accelerator Improvements - FY 1996, ANL-East (96-G-302)	0.6	-	-	0.6	-	-	-	-	-
39-KC-02									
Office of Energy Research									
Basic Energy Sciences									
Advanced Photon Source, Accelerator Improvements, ANL-East	4.7	-	-	4.7	-	-	-	-	-
39-KC-03									
Office of Energy Research									
Basic Energy Sciences									
Chemical Sciences									
General Plant Projects - FY 1996, ANL-East (GP-E-400)	7.0	-	-	7.0	-	-	-	-	-
39-WB-00									
Office of Associate Deputy Secretary for Field Management									
In-House Energy Management	2.0	-	-	2.0	-	-	-	-	-
Modifications for Energy Management									
TOTAL BUDGETED PROJECTS	22.0	0.0	0.0	19.2	2.8	0.0	0.0	0.0	0.0
TOTAL FUNDED AND BUDGETED PROJECTS	577.1	84.1	24.8	24.0	12.2	0.3	0.0	0.0	0.0

Table X.3 Major Construction Projects (Cont.)

	TEC	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Proposed Projects									
39-AF-95									
Office of Nuclear Energy, Science, and Technology									
Nuclear Energy Research and Development									
General Plant Projects, ANL-West	9.9	-	-	-	1.0	1.2	2.5	2.5	2.5
Modifications to Reactors	2.6	-	-	-	0.3	1.3	-	-	-
Waste Shipping Cask	4.6	-	-	-	-	4.6	-	-	-
Infrastructure Improvement, ANL-West	4.5	-	-	-	-	4.5	-	-	-
39-EX-31									
Office of Environmental Management									
Waste Management (Non-Defense)									
General Plant Projects, ANL-West	0.7	-	-	-	0.3	0.3	0.1	-	-
39-KB-00									
Office of Energy Research									
Nuclear Physics									
Accelerator Improvements, ANL-East (97-CH-023)	5.5	-	-	-	0.6	1.0	1.3	1.3	1.3
39-KC-02									
Office of Energy Research									
Basic Energy Sciences									
Advanced Photon Source, Accelerator Improvements, ANL-East (97-CH-071)	23.5	-	-	-	4.7	4.7	4.7	4.7	4.7
39-KC-03									
Office of Energy Research									
Basic Energy Sciences									
Chemical Sciences									
General Plant Projects, ANL-East (GP-E-400)	41.0	-	-	-	7.4	7.8	8.2	8.6	9.0

Table X.3 Major Construction Projects (Cont.)

	TEC	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Proposed Projects (Cont.)									
39-KG-01									
Office of Energy Research									
Multiprogram Energy Laboratories —									
General Purpose Facilities									
Building Replacement									
Central Supply Facility	7.7	-	-	-	0.6	4.2	2.9	-	-
Multiprogram Laboratory/Office Building I	13.0	-	-	-	-	-	0.9	7.0	5.1
Central Support Facility	9.8	-	-	-	-	-	-	-	0.7
Building Rehabilitation and Upgrade									
Building Mechanical and Control Systems Upgrade, Phase I	5.1	-	-	-	-	1.1	2.3	1.7	-
Electrical System Upgrade - Phase III	7.6	-	-	-	0.5	6.0	1.1	-	-
Laboratory Space Upgrade - Phase I	5.1	-	-	-	-	1.1	2.3	1.7	-
Building Electrical Service Upgrade - Phase II	5.1	-	-	-	-	1.1	2.3	1.7	-
Building Mechanical and Control Systems Upgrade, Phase II	5.4	-	-	-	-	-	-	1.2	2.4
Laboratory Space Upgrade - Phase II	5.4	-	-	-	-	-	-	1.2	2.4
Building Electrical Service Upgrade - Phase III	5.4	-	-	-	-	-	-	1.2	2.4
Rehabilitation and Upgrade of Utility Distribution Systems									
Steam System Upgrade	6.5	-	-	-	-	-	1.2	2.6	2.7
Roads/Parking/Walks/Street Lighting Upgrade	9.7	-	-	-	-	-	-	0.7	6.0
Electrical System Upgrade - Phase IV	7.5	-	-	-	-	-	-	-	1.1
39-KG-02									
Office of Energy Research									
Multiprogram Energy Laboratories —									
Environment, Safety, and Health Support									
Fire Safety Improvements - Phase IV	3.2	-	-	-	-	0.2	1.9	1.1	-
Fire Safety Improvements - Phase V	3.7	-	-	-	-	-	0.3	1.8	1.6
Fire Safety Improvements - Phase VI	5.3	-	-	-	-	-	-	0.7	2.6
Fire Safety Improvements - Phase VII	3.2	-	-	-	-	-	-	-	0.5
39-WB-00									
Office of Associate Deputy Secretary for Field Management									
In-House Energy Management									
Modifications for Energy Management	10.0	-	-	-	2.0	2.0	2.0	2.0	2.0

XI. Information Management

A. Overview

Information management at Argonne emphasizes the effective development, communication, and management of scientific, technical, operational, and business information. Because of the importance of these activities and the associated infrastructure, they are supported as part of research programs or through Laboratory indirect funds.

In keeping with DOE's mission, Argonne's research results are communicated to national and international audiences in the form of scientific and technical information, a primary product of the Laboratory. Laboratory programs are also major users of scientific and technical information generated elsewhere, as well as users of internal administrative data relating to the Laboratory's business and operational activities.

Cost-effective management of scientific, technical, and business information throughout its life cycle is critical to the Laboratory's success in fulfilling its mission. Information is managed at Argonne both as an integral aspect of each research program and as an institutional resource (see Sections XI.C and XI.D).

To manage information as an institutional resource, the Laboratory has established policy bodies and infrastructure to enable cost-effective information management that meets programmatic, operational, and administrative goals. The resources described in this chapter are greatly enriched by the Laboratory's advanced research programs and major initiatives in mathematics, computer science, and communications infrastructure (as summarized in Chapters IV and V). These programs and initiatives require continuing enhancement of the high-performance computer networks at Argonne (as detailed in Section XI.B).

A Laboratory-wide computing and information policy committee, comprising senior managers representing programmatic and operational interests at both major Argonne sites, advises executive management on infrastructure and service needs and on an overall strategic vision for computing, telecommunications, and information management to meet anticipated needs and to support Argonne's mission priorities. Working within this vision, Argonne service organizations and consensus-building oversight bodies define and implement Laboratory-wide information, telecommunications, and computing systems and services.

As required by Argonne's vision, all Laboratory organizations continually explore the application of emerging information technologies through the aggressive use of demonstrations and pilot projects. In concert with these efforts, Argonne continues to enhance the computer skills of its employees through mentoring and training. The overall objective is to maximize the ease and effectiveness with which information is acquired, created, modified, stored, retrieved, and applied at the Laboratory.

B. Communications Infrastructure

Argonne's internal and external communications infrastructure is kept current to support the Laboratory's strategic vision for computing, telecommunications, and information management and to facilitate programmatic collaborations, smooth functioning of Laboratory operations, and broad access to information resources. Argonne develops and employs systems to facilitate telecommuting and telework whenever they are found to be beneficial.

1. Networking

During 1995, Argonne moved from a mainframe-based computing environment to a

distributed environment to meet both research and administrative needs for computation and information management. The cornerstone for success in the distributed environment is the availability of high-speed networks that transparently link all computer users to the information resources they need at Argonne and throughout the nation and world. Both on-site research computing and staff collaboration with other research organizations necessitate increasingly sophisticated and powerful communications links.

At each of Argonne's two major sites, the sitewide computing network and telecommunications systems are the responsibility of a single service organization. Each organization provides networked resources that link the distributed high-performance desktop workstations used for scientific, engineering, and administrative applications. These resources allow Argonne's research programs to explore and deploy evolving computing technologies, while they ensure the integrity of the operational network.

At its Illinois site, Argonne operates a digital private branch exchange (PBX) telephone system, which supports integrated services digital network (ISDN) trunking for commercial and FTS2000 services. A complementary ISDN system integrates data and networking capabilities of the public switched ISDN services, providing enhanced networking and video teleconferencing connections with parties ranging from small businesses or local governments exploring collaborative ventures with Argonne to employees traveling or working away from the office. Argonne plans to use ISDN not only for voice trunking and high-speed data communications but also as an infrastructure for sitewide videoconferencing linked to switched commercial and FTS2000 ISDN services.

For the time beyond FTS2000, Argonne plans to take full advantage of the competitive market forces that will develop quickly under new contract structures. The central objective will be to maximize cost efficiencies but provide optimal voice, data, and video network services that can be reconfigured quickly if any single carrier fails. Carriers will be encouraged to provide all voice, data, and video network services via dedicated fiber-optic cable rather than copper wire or microwave facilities.

At Argonne-East, networking facilities include a 100-megabit/second fiber distributed data interface (FDDI) backbone operating on a fiber-optic cable plant that also supports a bridged Ethernet network throughout the Laboratory and a 1-megabit/second LANmark capability provided by the PBX system. Argonne has identified the FDDI and asynchronous transfer mode (ATM) standards as an important basis for future high-speed sitewide networks; the current fiber-optic cable plant will allow deployment of these standard technologies to support bandwidths into the gigabit/second range.

In addition, Argonne-East has installed a central cluster of high-performance workstations and servers, accessible by network to support the ongoing migration of application software and databases from mainframe to distributed systems, for both research computing and administrative information management. The new central machines are used as file servers for network management and also to ensure the integrity of a distributed environment that includes both client-server and terminal-host systems. These resources also serve customers within the Laboratory who choose not to operate their own computer systems.

At Argonne-West, campus data communications are provided by a star topology fiber-optic Ethernet network with high-performance routing between subnets, an FDDI interface for future high-bandwidth requirements, and a T1 link to Argonne-East. A cluster of personal computer network servers supports distributed application software and databases for administrative and engineering work.

Argonne continues to deploy network infrastructure and create technical partnerships with network service providers that result in attractive Internet access. The Laboratory maintains national network connections such as ESnet (a DOE Energy Research network), CICNet (a midwestern regional network), and MREN (a high-speed test network in the Chicago metropolitan area). All of these

external networks interface with Argonne networks via ATM, FDDI firewall, and on-site Ethernet firewall networks.

Argonne has aggressively deployed high-performance networks (employing ATM and other technologies) to support DOE initiatives such as DOE2000. The Laboratory led a nationwide project to connect government and private network test beds, creating a national facility. (This effort is called the I-WAY, for Information Wide Area Year.)

2. Collaborative Information Management Initiatives

Argonne's development of high-speed site networks supports National Information Infrastructure initiatives. Industry and governmental standards will be implemented to improve interoperability between Argonne and other DOE sites, under DOE's Information Architecture Initiative. Argonne actively participates in DOE standards committees and task groups supporting this initiative.

Argonne is working with the National Energy Research Supercomputer Center (NERSC) and three other national laboratories (Lawrence Livermore, Pacific Northwest, and Sandia) on the DOE ESnet Authentication pilot project. The goal is to develop cross-realm authentications for the ESnet wide area network. With NERSC and four other national laboratories (Brookhaven, Lawrence Berkeley, Los Alamos, and Oak Ridge), Argonne recently participated in a DOE pilot project on ATM high-speed, high-performance local area networks. The goal is to investigate high-performance local area network environments in preparation for the advanced fast-packet-switching services to be offered in the ESnet wide area network.

3. Radio Communications

In the area of wireless communications, the Emerging Telecommunication Act of 1993 requires that all radio equipment purchased after January 1, 1995, conform to new narrowband frequency standards. By 2005, all frequency allocations and spectrum-dependent equipment must meet the new standards. Moving to digital radio trunking systems will meet this requirement, thereby conserving the frequency spectrum for other national priorities. This move will require the Laboratory to upgrade all its radio equipment, at a total cost of about $2.5 million.

C. Administrative Information Management

Consistent with the Laboratory's strategic vision for computing and information management, Argonne maintains a high level of expertise in computing and keeps in step with rapidly developing computing technologies, in order to streamline business operations and to support research programs. Argonne's computer users, especially those in support organizations, increasingly exchange information electronically across networked servers and workstations, facilitating efficient management of information resources. This enhanced computing environment decreases costs and improves both productivity and the quality of service.

Argonne treats administrative information systems — such as those for finance, human resources, procurement, and records management — as critical institutional resources. Required strategic planning, funding arrangements, and coordinated management are addressed collaboratively by several review and implementation teams. The strategic planning process links programmatic missions, operational business goals, and administrative information system functions through an administrative data processing oversight committee. The Laboratory's general strategy for administrative computing is to exploit new technology for improving service to Laboratory users, to manage information as a resource, and

to reengineer for greater efficiency and cost-effectiveness where new technology allows.

Argonne's transition of administrative information systems from a mainframe environment to a distributed, largely client-server environment was completed in early 1996. The result is a set of networked, distributed systems that capitalize on commercial relational database applications as well as on the productivity-enhancing features of personal computers and high-performance workstations.

The new distributed administrative information systems environment integrates previously independent systems, increases data accessibility, and incorporates users into the process of designing and developing the system. Client-server systems now in place allow Argonne to improve management of information resources by creating easily accessible on-line repositories for corporate operating data and archives, thereby reducing duplication and improving data integrity. The new systems ultimately will have many advantages, including convenient electronic exchange of data, extensive use of image scanning and point-of-transaction data entry, and electronic authorization with network-wide authentication regardless of the data entry point.

D. Scientific and Technical Information Management

To support the Laboratory's strategic vision for computing and information management, Argonne continually works to enhance the availability, use, exchange, and management of scientific and technical information in electronic form. This effort includes distributing documents electronically both internally and externally, publishing electronically, and exploiting multimedia technologies.

Within each research program at Argonne, scientific and technical information is acquired, created, and communicated in a customized fashion fitted to the objectives of the programs. This decentralized approach recognizes that the life cycle management of programmatic information must be tightly interwoven with the underlying research in order to meet fully the expectations of the Laboratory's sponsors. Principal investigators are empowered to manage the information for their programs in ways consistent with the sponsors' requirements, with support from a variety of Laboratory resources.

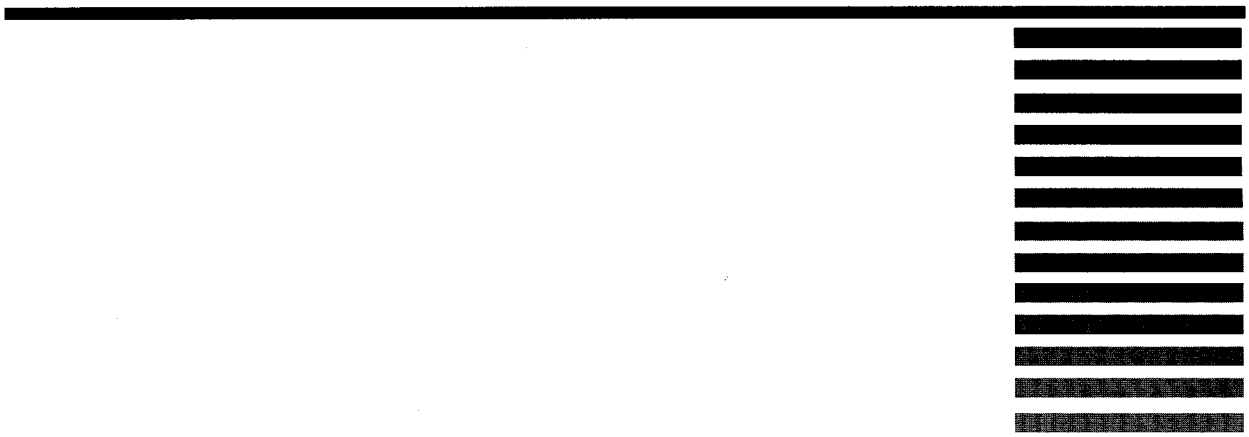
At each major Argonne site, a single support organization provides services and infrastructure for the publication and management of scientific and technical information over its full life cycle, helping both research and operations organizations to find, use, and communicate information effectively.

Publication services support both paper and electronic distribution of information. Current services include communication planning, writing, editing, video production, digital and traditional photography, illustration, and all phases of production for information disseminated via paper, videotape, compact disk, the Internet, and other electronic means. Services under development include digital on-demand printing, multimedia production, and electronic publishing in hypertext markup language (HTML) and standard generalized markup language (SGML). Argonne is a charter participant in DOE's ongoing SGML initiative for scientific and technical information.

Argonne's electronic "library of the future" gives research staff fast, convenient access to critical information resources. A growing collection of electronic information products is gradually replacing the library system's paper collection, with access through a Laboratory-wide library and text management system. This system provides desktop access to on-site and off-site text databases, catalogs of library holdings, and listings of Laboratory publications; it will soon link to electronic versions of Laboratory policy and procedure manuals and records inventories. The new records inventory database will facilitate active management of records throughout their life cycle, complementing Argonne's ongoing participation in DOE's records inventory and management initiative.

Resources

Strategic planning for the Department of Energy and its laboratories ultimately becomes an issue of resource allocation. This concluding Chapter XII of the *Institutional Plan* projects the resources required for established Laboratory programs to continue their contributions to DOE and national goals over a five-year time horizon. Funding for the R&D initiatives presented in Chapters IV and V must also be considered to obtain a comprehensive view of requirements for Argonne to realize fully its strategic potential.



XII. Projections of Funding and Effort

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 1996 generally are not included in these resource projections. Funds received in FY 1995 and FY 1996 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 XII.1 and XII.19, which also specify funding for proposed construction projects.

The figures for FY 1995 and FY 1996 represent historical dollar values. Projections to FY 1997 incorporate annual cost escalation of 5.4% for effort and 3.7% for materials and services. Escalation rates for FY 1998 are, respectively, 5.4% and 3.7%. Operating costs beyond FY 1998 are expressed in FY 1998 dollars.

The year-to-year escalation rates for construction costs, from FY 1997 to FY 2002, are provided by DOE.

The resource projections are presented in 21 tables:

- Tables XII.1 and XII.2 summarize Laboratory total funding and personnel levels, respectively.
- Tables XII.3-XII.18 give operating, capital equipment, and construction funding along with personnel levels for each subprogram within specified DOE secretarial offices and for work supported by non-DOE agencies. Tables XII.3-XII.16 describe work funded by DOE, Table XII.17 lists work funded by DOE contractors, and Table XII.18 pertains to work funded by all other organizations.
- Table XII.19 summarizes the information in Tables XII.3-XII.18, giving total Laboratory funding for each DOE secretarial office.
- Tables XII.20 and XII.21 summarize subcontracting and procurement at the Laboratory, with the latter table detailing procurements from small and disadvantaged businesses.

Table XII.1 Laboratory Funding Summary ($ in millions BA)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
DOE Effort	403.9	390.6	418.5	451.5	451.2	455.7	455.7	456.0
Transfer to Other DOE Contractors	(5.3)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)
Work for Sponsors Other than DOE	77.0	63.7	62.6	60.2	59.5	59.3	59.3	59.3
Total Operating	475.6	451.3	478.1	508.7	507.7	512.0	512.0	512.3
Capital Equipment	19.1	26.9	21.2	28.6	28.7	29.1	29.1	29.1
Construction	92.3[a]	12.8	9.9	2.8	0.0	0.0	0.0	0.0
Inventory	1.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2
General Purpose Equipment[b]	2.2	2.2	3.7	3.9	4.1	4.3	4.5	4.7
General Plant Projects[b]	4.2	4.7	9.3	8.7	9.3	10.8	11.1	11.5
Multiprogram Energy Laboratories — Facilities Support Program	5.0	7.3	4.8	9.4	0.3	0.0	0.0	0.0
Total Laboratory Funding	599.6	505.3	527.1	562.3	550.3	556.4	556.9	557.8
Proposed Projects								
Program Construction	0.0	0.0	0.0	7.6	18.1	8.0	8.0	8.0
Multiprogram Energy Laboratories — Facilities Support Program	0.0	0.0	0.0	1.1	13.7	15.2	22.6	27.5
Total Projected Funding	599.6	505.3	527.1	571.0	582.1	579.6	587.5	593.3

[a]Includes state of Illinois APS housing construction.

[b]Includes projections of resources to be provided by DOE-ER for Argonne-East, by DOE-NE for Argonne-West, and by DOE-EM for both sites.

Table XII.2 Laboratory Personnel Summary (in FTE)[a]

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Direct Personnel								
DOE Effort	2181.9	2180.2	2099.9	2124.3	2122.2	2124.6	2124.6	2124.6
Work for Sponsors Other than DOE	328.9	300.4	277.7	263.0	259.1	258.0	253.6	253.6
Total Operating	2510.8	2480.6	2377.6	2387.3	2381.3	2382.6	2378.2	2378.2
Other Direct	827.2	802.5	766.2	769.4	767.5	767.8	766.5	766.5
Total Direct Personnel	3338.0	3283.1	3143.8	3156.7	3148.8	3150.4	3144.7	3144.7
Indirect Personnel	1649.0	1644.1	1578.9	1585.4	1581.4	1582.2	1579.4	1579.4
Total Personnel	4987.0	4927.2	4722.7	4742.1	4730.2	4732.6	4724.1	4724.1

[a]Technical service personnel are included in the direct personnel projections.

Table XII.3 Nuclear Energy, Science and Technology: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Nuclear Energy Research and Development (AF)								
Operating	98.9	92.5	97.4	98.1	98.9	102.0	102.0	102.0
Capital Equipment	1.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0
General Purpose Equipment	–	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Construction	3.4	1.7	2.2	–	–	–	–	–
General Plant Projects	1.6	–	2.0	1.0	1.2	2.5	2.5	2.5
Total	104.9	97.4	102.8	100.3	101.3	105.7	105.7	105.7
Direct Personnel	506.1	548.8	541.8	509.8	509.0	509.0	509.0	509.0
Uranium Enrichment Activities (CD-10)								
Operating	1.3	3.2	1.0	0.2	0.2	0.2	0.2	0.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.3	3.2	1.0	0.2	0.2	0.2	0.2	0.2
Direct Personnel	3.2	15.0	5.0	1.0	1.0	1.0	1.0	1.0
Policy and Management (KK-05)								
Operating	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.3	0.2	–	–	–	–	–	–
Total Nuclear Energy, Science and Technology								
Operating	100.5	95.9	98.6	98.5	99.3	102.4	102.4	102.4
Capital Equipment	1.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0
General Purpose Equipment	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Construction	3.4	1.7	2.2	0.0	0.0	0.0	0.0	0.0
General Plant Projects	1.6	0.0	2.0	1.0	1.2	2.5	2.5	2.5
Total	106.5	100.8	104.0	100.7	101.7	106.1	106.1	106.1
Direct Personnel	509.6	564.0	546.8	510.8	510.0	510.0	510.0	510.0

Table XII.4 Energy Research: Resources by Subprogram ($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Magnetic Fusion (AT)								
Operating	7.1	5.3	7.1	7.1	7.1	7.1	7.1	7.1
Capital Equipment	0.7	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Construction	–	–	–	–	–	–	–	–
Total	7.8	5.4	7.3	7.3	7.3	7.3	7.3	7.3
Direct Personnel	30.3	29.6	31.8	32.3	32.3	32.3	32.3	32.3
Analytic Technology (KP-01)								
Operating	0.3	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.3	–	–	–	–	–	–	–
Direct Personnel	2.7	0.2	–	–	–	–	–	–
Environmental Research (KP-02)								
Operating	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Capital Equipment	<0.1	<0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	–	–	–	–	–	–	–	–
Total	2.1	2.0	2.1	2.1	2.1	2.1	2.1	2.1
Direct Personnel	16.9	16.0	16.0	16.0	16.0	16.0	16.0	16.0
Health Effects Research (KP-03)								
Operating	3.6	1.5	1.7	1.7	1.7	1.7	1.7	1.7
Capital Equipment	<0.1	<0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	–	–	–	–	–	–	–	–
Total	3.6	1.5	1.8	1.8	1.8	1.8	1.8	1.8
Direct Personnel	26.0	7.5	8.0	8.0	8.0	8.0	8.0	8.0
General Life Sciences (KP-04)								
Operating	4.8	6.6	7.6	8.0	8.0	8.0	8.0	8.0
Capital Equipment	0.3	0.4	1.2	1.1	1.1	1.1	1.1	1.1
Construction	6.7	4.3	–	–	–	–	–	–
Total	11.8	11.3	8.8	9.1	9.1	9.1	9.1	9.1
Direct Personnel	44.1	48.0	48.0	48.0	48.0	48.0	48.0	48.0
Carbon Dioxide Research (KP-05)								
Operating	0.8	1.1	1.2	1.2	1.2	1.2	1.2	1.2
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	–	–	–	–	–	–	–	–
Total	0.9	1.2	1.3	1.3	1.3	1.3	1.3	1.3
Direct Personnel	5.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0

Table XII.4 Energy Research: Resources by Subprogram (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Total Biological and Environmental Research (KP)								
Operating	11.6	11.2	12.5	12.9	12.9	12.9	12.9	12.9
Capital Equipment	0.4	0.5	1.5	1.4	1.4	1.4	1.4	1.4
Construction	6.7	4.3	0.0	0.0	0.0	0.0	0.0	0.0
Total	18.7	16.0	14.0	14.3	14.3	14.3	14.3	14.3
Direct Personnel	95.2	77.7	78.0	78.0	78.0	78.0	78.0	78.0
High Energy Physics — Physics Research (KA-01)								
Operating	5.7	5.6	5.6	5.9	6.0	6.0	6.0	6.0
Capital Equipment	0.7	0.7	1.7	2.4	2.5	2.5	2.5	2.5
Construction	–	–	–	–	–	–	–	–
Total	6.4	6.3	7.3	8.3	8.5	8.5	8.5	8.5
Direct Personnel	39.4	37.3	38.8	40.9	41.0	41.0	41.0	41.0
High Energy Physics — High Energy Technology (KA-03)								
Operating	2.2	2.4	2.5	2.6	3.2	3.4	3.4	3.4
Capital Equipment	0.2	0.2	1.1	1.1	0.6	1.0	1.0	1.0
Construction	–	–	–	–	–	–	–	–
Total	2.4	2.6	3.6	3.7	3.8	4.4	4.4	4.4
Direct Personnel	14.5	15.3	17.0	17.0	18.9	18.9	18.9	18.9
Total High Energy Physics (KA)								
Operating	7.9	8.0	8.1	8.5	9.2	9.4	9.4	9.4
Capital Equipment	0.9	0.9	2.8	3.5	3.1	3.5	3.5	3.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	8.8	8.9	10.9	12.0	12.3	12.9	12.9	12.9
Direct Personnel	53.9	52.6	55.8	57.9	59.9	59.9	59.9	59.9
Medium Energy Nuclear Physics (KB-01)								
Operating	2.9	3.1	3.1	3.7	3.7	3.7	3.7	3.7
Capital Equipment	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Construction	–	–	–	–	–	–	–	–
Total	3.2	3.3	3.4	4.0	4.0	4.0	4.0	4.0
Direct Personnel	16.0	16.8	17.3	18.7	18.7	18.7	18.7	18.7

Table XII.4 Energy Research: Resources by Subprogram (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Heavy-Ion Nuclear Physics (KB-02)								
Operating	9.6	9.9	10.0	12.8	12.8	12.8	12.8	12.8
Capital Equipment	1.1	1.1	1.1	1.5	1.5	1.5	1.5	1.5
Construction	0.5	0.3	0.6	–	–	–	–	–
Total	11.2	11.3	11.7	14.3	14.3	14.3	14.3	14.3
Direct Personnel	60.6	65.7	65.7	74.3	74.3	74.3	74.3	74.3
Nuclear Theory Physics (KB-03)								
Operating	0.9	0.9	0.9	1.3	1.3	1.3	1.3	1.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.9	0.9	0.9	1.3	1.3	1.3	1.3	1.3
Direct Personnel	6.0	8.3	7.1	8.5	8.5	8.5	8.5	8.5
Low Energy Nuclear Physics (KB-04)								
Operating	0.2	0.3	0.3	1.2	1.2	1.2	1.2	1.2
Capital Equipment	–	–	–	0.3	0.3	0.3	0.3	0.3
Construction	–	–	–	–	–	–	–	–
Total	0.2	0.3	0.3	1.5	1.5	1.5	1.5	1.5
Direct Personnel	1.0	1.4	1.6	5.8	5.8	5.8	5.8	5.8
Total Nuclear Physics (KB)								
Operating	13.6	14.2	14.3	19.0	19.0	19.0	19.0	19.0
Capital Equipment	1.4	1.3	1.4	2.1	2.1	2.1	2.1	2.1
Construction	0.5	0.3	0.6	0.0	0.0	0.0	0.0	0.0
Total	15.5	15.8	16.3	21.1	21.1	21.1	21.1	21.1
Direct Personnel	83.6	92.2	91.7	107.3	107.3	107.3	107.3	107.3
Materials Sciences (KC-02)								
Operating	23.0	27.6	28.2	42.0	42.0	42.0	42.0	42.0
Capital Equipment	2.0	6.1	4.7	7.2	7.2	7.2	7.2	7.2
Construction	–	–	–	–	–	–	–	–
Total	25.0	33.7	32.9	49.2	49.2	49.2	49.2	49.2
Direct Personnel	128.2	153.5	167.6	179.5	179.5	179.5	179.5	179.5

Table XII.4 Energy Research: Resources by Subprogram (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Advanced Photon Source (KC-02)								
Operating	64.9	76.9	80.0	92.0	92.0	92.0	92.0	92.0
Capital Equipment	3.9	7.3	2.6	7.0	7.0	7.0	7.0	7.0
Construction	75.8[a]	3.2	4.7	–	–	–	–	–
Total	144.6	87.4	87.3	99.0	99.0	99.0	99.0	99.0
Direct Personnel	408.4	408.4	404.3	416.6	416.6	416.6	416.6	416.6
Total Materials Sciences (KC-02)								
Operating	87.9	104.5	108.2	134.0	134.0	134.0	134.0	134.0
Capital Equipment	5.9	13.4	7.3	14.2	14.2	14.2	14.2	14.2
Construction	75.8	3.2	4.7	0.0	0.0	0.0	0.0	0.0
Total	169.6	121.1	120.2	148.2	148.2	148.2	148.2	148.2
Direct Personnel	536.6	561.9	571.9	596.1	596.1	596.1	596.1	596.1
Chemical Sciences (KC-03)								
Operating	15.9	15.8	15.8	16.5	17.6	18.8	18.8	18.8
Capital Equipment	2.2	2.0	2.0	2.2	2.2	2.2	2.2	2.2
General Purpose Equipment	2.2	2.0	3.5	3.7	3.9	4.1	4.3	4.5
Construction	–	–	–	–	–	–	–	–
General Plant Projects	2.2	4.3	7.0	7.4	7.8	8.2	8.6	9.0
Total	22.5	24.1	28.3	29.8	31.5	33.3	33.9	34.5
Direct Personnel	86.0	85.0	83.0	85.0	87.5	90.0	90.0	90.0
Engineering and Geosciences (KC-04)								
Operating	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	–	–	–	–	–	–	–	–
Total	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Direct Personnel	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Total Basic Energy Sciences (KC-02, KC-03, KC-04)								
Operating	104.4	120.9	124.6	151.1	152.2	153.4	153.4	153.4
Capital Equipment	8.2	15.5	9.4	16.5	16.5	16.5	16.5	16.5
General Purpose Equipment	2.2	2.0	3.5	3.7	3.9	4.1	4.3	4.5
Construction	75.8	3.2	4.7	0.0	0.0	0.0	0.0	0.0
General Plant Projects	2.2	4.3	7.0	7.4	7.8	8.2	8.6	9.0
Total	192.8	145.9	149.2	178.7	180.4	182.2	182.8	183.4
Direct Personnel	625.6	650.9	658.9	685.1	687.6	690.1	690.1	690.1

Table XII.4 Energy Research: Resources by Subprogram (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Advanced Energy Projects (KC-05)								
Operating	0.3	0.6	0.9	0.9	0.9	0.9	0.9	0.9
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.3	0.6	0.9	0.9	0.9	0.9	0.9	0.9
Direct Personnel	2.2	4.0	5.5	5.5	5.5	5.5	5.5	5.5
Applied Mathematical Sciences Program (KC-07)								
Operating	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.5
Capital Equipment	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3
Construction	–	–	–	–	–	–	–	–
Total	11.4	11.4	11.4	11.4	11.5	11.5	11.5	11.8
Direct Personnel	30.7	29.0	28.5	28.5	28.5	28.5	28.5	28.5
Laboratory Technology Research Program (KU)								
Operating	9.6	2.8	6.0	10.0	10.0	10.0	10.0	10.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	9.6	2.8	6.0	10.0	10.0	10.0	10.0	10.0
Direct Personnel	68.7	54.4	44.3	68.9	68.9	68.9	68.9	68.9
Total Computational and Technology Research (KC-05, KC-07, KU)								
Operating	21.1	14.6	18.1	22.1	22.1	22.1	22.1	22.4
Capital Equipment	0.2	0.2	0.2	0.2	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	21.3	14.8	18.3	22.3	22.4	22.4	22.4	22.7
Direct Personnel	101.6	87.4	78.3	102.9	102.9	102.9	102.9	102.9
Energy Research Analysis (KD)								
Operating	0.4	0.5	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.4	0.5	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	0.2	3.7	1.0	0.6	0.6	0.6	0.6	0.6

Table XII.4 Energy Research: Resources by Subprogram (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Total Energy Research								
Operating	166.1	174.7	184.8	220.8	222.6	224.0	224.0	224.3
Capital Equipment	11.8	18.5	15.5	23.9	23.6	24.0	24.0	24.0
General Purpose Equipment	2.2	2.0	3.5	3.7	3.9	4.1	4.3	4.5
Construction	83.0	7.8	5.3	0.0	0.0	0.0	0.0	0.0
General Plant Projects	2.2	4.3	7.0	7.4	7.8	8.2	8.6	9.0
Subtotal	265.3	207.3	216.1	255.8	257.9	260.3	260.9	261.8
Inventory	1.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2
Multiprogram Energy Laboratories — Facilities Support Program	5.0	7.3	4.8	9.4	0.3	0.0	0.0	0.0
Total Energy Research	271.5	214.7	221.0	265.4	258.4	260.5	261.1	262.0
Direct Personnel	990.4	994.1	995.5	1064.1	1068.6	1071.1	1071.1	1071.1

[a]Includes state of Illinois APS housing construction.

Table XII.5 Science Education and Technical Information ($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
University and Science Education (KT)								
Operating	4.8	2.2	3.3	3.3	3.3	3.3	3.3	3.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	4.8	2.2	3.3	3.3	3.3	3.3	3.3	3.3
Direct Personnel	16.2	11.1	12.0	12.0	12.0	12.0	12.0	12.0

Table XII.6 Energy Efficiency and Renewable Energy: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Electric Field Effects (AK-04)								
Operating	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	1.1	1.0	1.5	1.5	1.5	1.5	1.5	1.5
Systems Technology (AK-06)								
Operating	4.1	3.2	4.0	5.0	5.0	5.0	5.0	5.0
Capital Equipment	–	–	0.4	0.5	0.5	0.5	0.5	0.5
Construction	–	–	–	–	–	–	–	–
Total	4.1	3.2	4.4	5.5	5.5	5.5	5.5	5.5
Direct Personnel	18.6	13.1	13.1	21.5	21.5	21.5	21.5	21.5
Total Electric Energy Systems (AK)								
Operating	4.3	3.4	4.3	5.3	5.3	5.3	5.3	5.3
Capital Equipment	0.0	0.0	0.4	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
Total	4.3	3.4	4.7	5.8	5.8	5.8	5.8	5.8
Direct Personnel	19.7	14.1	14.6	23.0	23.0	23.0	23.0	23.0
Solar Thermal Energy Systems (EB-23)								
Operating	<0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	0.3	0.3	–	–	–	–	–	–
Biofuels Energy Systems (EB-24)								
Operating	0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	–	–	–	–	–	–	–
Direct Personnel	0.5	0.1	–	–	–	–	–	–

Table XII.6 Energy Efficiency and Renewable Energy: Resources by Subprogram (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Solar International Program (EB-27)								
Operating	0.2	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	–	–	–	–	–	–	–
Direct Personnel	1.1	0.3	–	–	–	–	–	–
Building Systems (EC-10)								
Operating	0.1	0.6	0.7	0.7	0.7	0.7	0.7	0.7
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	0.6	0.7	0.7	0.7	0.7	0.7	0.7
Direct Personnel	0.7	2.8	2.9	2.9	2.9	2.9	2.9	2.9
Federal Energy Management Program (EC-26)								
Operating	<0.1	<0.1	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	0.1	0.1	–	–	–	–	–	–
Cogeneration (ED-20)								
Operating	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	1.5	1.1	0.6	0.6	0.6	0.6	0.6	0.6
Process Heating and Cooling (ED-21)								
Operating	0.7	–	–	–	–	–	–	–
Capital Equipment	0.1	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.8	–	–	–	–	–	–	–
Direct Personnel	4.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Materials Processing and Metals (ED-22)								
Operating	–	1.5	2.0	1.0	1.0	1.0	1.0	1.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	1.5	2.0	1.0	1.0	1.0	1.0	1.0
Direct Personnel	1.1	2.2	1.4	1.4	1.4	1.4	1.4	1.4

Table XII.6 Energy Efficiency and Renewable Energy: Resources by Subprogram (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Other Process Efficiency (ED-23)								
Operating	1.7	2.0	4.1	5.0	5.0	5.0	5.0	5.0
Capital Equipment	0.1	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.8	2.0	4.1	5.0	5.0	5.0	5.0	5.0
Direct Personnel	8.0	11.2	16.1	19.6	19.6	19.6	19.6	19.6
Industrial Wastes (ED-30)								
Operating	3.7	2.5	6.0	6.0	6.0	6.0	6.0	6.0
Capital Equipment	0.3	0.1	0.3	0.6	0.6	0.6	0.6	0.6
Construction	–	–	–	–	–	–	–	–
Total	4.0	2.6	6.3	6.6	6.6	6.6	6.6	6.6
Direct Personnel	19.1	23.3	29.3	28.8	28.8	28.8	28.8	28.8
Municipal Solid Wastes (ED-31)								
Operating	<0.1	<0.1	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	0.1	0.1	–	–	–	–	–	–
Implementation and Development (ED-41)								
Operating	0.2	<0.1	0.1	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	–	0.1	–	–	–	–	–
Direct Personnel	0.7	0.2	0.3	–	–	–	–	–
Total Industrial (ED)								
Operating	6.5	6.1	12.3	12.1	12.1	12.1	12.1	12.1
Capital Equipment	0.5	0.1	0.3	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	7.0	6.2	12.6	12.7	12.7	12.7	12.7	12.7
Direct Personnel	34.7	38.3	47.9	50.6	50.6	50.6	50.6	50.6
Alternative Fuels Utilization (EE-50)								
Operating	1.0	1.5	2.5	2.6	2.6	2.6	2.6	2.6
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.0	1.5	2.5	2.6	2.6	2.6	2.6	2.6
Direct Personnel	7.5	8.0	10.9	11.6	11.6	11.6	11.6	11.6

Table XII.6 Energy Efficiency and Renewable Energy: Resources by Subprogram (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Materials Development (EE-51)								
Operating	0.6	1.1	1.3	1.2	1.2	1.2	1.2	1.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.6	1.1	1.3	1.2	1.2	1.2	1.2	1.2
Direct Personnel	6.0	6.1	6.2	4.6	4.6	4.6	4.6	4.6
Heat Engine Development (EE-52)								
Operating	1.2	0.7	0.7	0.5	0.5	0.5	0.5	0.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.2	0.7	0.7	0.5	0.5	0.5	0.5	0.5
Direct Personnel	8.5	5.9	3.9	2.7	2.7	2.7	2.7	2.7
Electric and Hybrid Propulsion (EE-53)								
Operating	2.6	3.8	4.5	5.4	5.4	5.4	5.4	5.4
Capital Equipment	0.1	0.3	0.6	0.5	0.5	0.5	0.5	0.5
Construction	–	–	–	–	–	–	–	–
Total	2.7	4.1	5.1	5.9	5.9	5.9	5.9	5.9
Direct Personnel	19.7	20.4	16.2	17.7	17.7	17.7	17.7	17.7
Implementation and Deployment (EE-54)								
Operating	1.3	1.6	1.5	1.8	1.8	1.8	1.8	1.8
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.3	1.6	1.5	1.8	1.8	1.8	1.8	1.8
Direct Personnel	4.8	5.4	7.7	8.3	8.3	8.3	8.3	8.3
Management (EE-55)								
Operating	0.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3
Direct Personnel	1.4	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Total Transportation (EE)								
Operating	6.9	9.9	11.8	12.8	12.8	12.8	12.8	12.8
Capital Equipment	0.1	0.3	0.6	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
Total	7.0	10.2	12.4	13.3	13.3	13.3	13.3	13.3
Direct Personnel	47.9	52.3	51.4	51.4	51.4	51.4	51.4	51.4

Table XII.6 Energy Efficiency and Renewable Energy: Resources by Subprogram (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Technical and Financial Assistance (EF)								
Operating	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	1.7	0.9	0.8	0.8	0.8	0.8	0.8	0.8
In-House Energy Management (WB)								
Operating	0.3	0.3	0.3	0.3	–	–	–	–
Capital Equipment	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Construction	2.3	2.0	2.0	–	–	–	–	–
Total	3.6	3.3	3.3	1.3	1.0	1.0	1.0	1.0
Direct Personnel	2.0	2.0	2.0	2.0	–	–	–	–
Total Energy Efficiency and Renewable Energy								
Operating	18.6	20.4	29.5	31.3	31.0	31.0	31.0	31.0
Capital Equipment	1.6	1.4	2.3	2.6	2.6	2.6	2.6	2.6
Construction	2.3	2.0	2.0	0.0	0.0	0.0	0.0	0.0
Total	22.5	23.8	33.8	33.9	33.6	33.6	33.6	33.6
Direct Personnel	108.7	111.2	119.6	130.7	128.7	128.7	128.7	128.7

Table XII.7 Fossil Energy: Resources by Subprogram ($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Control Technology and Coal Preparation (AA-10)								
Operating	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	0.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Advanced Research and Technology (AA-15)								
Operating	1.6	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.6	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Direct Personnel	10.6	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Advanced Cleaned Power Systems (AA-20)								
Operating	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	6.1	3.5	3.0	3.0	3.0	3.0	3.0	3.0
Drying Low Ranked Coals (AA-25)								
Operating	0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	–	–	–	–	–	–	–
Direct Personnel	0.5	–	–	–	–	–	–	–
Total Coal (AA)								
Operating	2.6	2.3	2.3	2.3	2.3	2.3	2.3	2.3
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	2.6	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Direct Personnel	17.8	13.5	13.0	13.0	13.0	13.0	13.0	13.0

Table XII.7 Fossil Energy: Resources by Subprogram (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Gas Utilization (AB-05)								
Operating	0.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Direct Personnel	6.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Fuel Cells (AB-45)								
Operating	0.7	0.7	1.3	1.4	1.4	1.4	1.4	1.4
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.7	0.7	1.3	1.4	1.4	1.4	1.4	1.4
Direct Personnel	5.0	3.5	5.7	6.3	6.3	6.3	6.3	6.3
Total Gas (AB)								
Operating	1.3	1.6	2.2	2.3	2.3	2.3	2.3	2.3
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	1.3	1.6	2.2	2.3	2.3	2.3	2.3	2.3
Direct Personnel	11.9	8.5	10.7	11.3	11.3	11.3	11.3	11.3
Oil Technology Recovery (AC-10)								
Operating	1.6	0.8	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.6	0.8	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	13.5	7.5	4.5	4.0	4.0	4.0	4.0	4.0
Fuels Programs (AU-02)								
Operating	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	9.1	5.4	1.8	1.8	1.8	1.8	1.8	1.8
Magnetohydrodynamics (AW-05)								
Operating	0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	–	–	–	–	–	–	–
Direct Personnel	1.0	0.5	–	–	–	–	–	–

Table XII.7 Fossil Energy: Resources by Subprogram (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Clean Coal Technology (AZ-02)								
Operating	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	1.4	2.0	0.3	0.3	0.3	0.3	0.3	0.3
Total Fossil Energy								
Operating	6.4	5.1	5.4	5.5	5.5	5.5	5.5	5.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	6.4	5.1	5.4	5.5	5.5	5.5	5.5	5.5
Direct Personnel	54.7	37.4	30.3	30.4	30.4	30.4	30.4	30.4

Table XII.8 Fissile Materials Disposition ($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Fissile Materials Disposition (GA)								
Operating	0.6	0.9	1.0	1.2	1.2	1.2	1.2	1.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.6	0.9	1.0	1.2	1.2	1.2	1.2	1.2
Direct Personnel	1.2	4.8	5.3	6.1	6.1	6.1	6.1	6.1

Table XII.9 Defense Programs: Resources by Subprogram ($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Other Weapons Activities (GB)								
Operating	1.3	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.3	–	–	–	–	–	–	–
Direct Personnel	12.0	1.2	–	–	–	–	–	–
New Production Reactors (NP)								
Operating	<0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	–	–	–	–	–	–	–	–
Weapons Activities (DP)								
Operating	–	2.1	0.8	0.8	0.8	0.8	0.8	0.8
Capital Equipment	–	–	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Construction	–	–	–	–	–	–	–	–
Total	–	2.1	0.8	0.8	0.8	0.8	0.8	0.8
Direct Personnel	–	16.8	4.6	3.5	3.5	3.6	3.6	3.6
Total Defense Programs								
Operating	1.3	2.1	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	1.3	2.1	0.8	0.8	0.8	0.8	0.8	0.8
Direct Personnel	12.0	18.0	4.6	3.5	3.5	3.6	3.6	3.6

Table XII.10 Nonproliferation and National Security: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Nonproliferation and Verification Research and Development (GC)								
Operating	2.7	1.9	2.0	2.1	2.1	2.1	2.1	2.1
Capital Equipment	0.3	<0.1	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	3.0	1.9	2.0	2.1	2.1	2.1	2.1	2.1
Direct Personnel	11.9	11.6	9.6	9.5	9.5	9.5	9.5	9.5
Nuclear Safeguards and Security (GD)								
Operating	0.4	0.1	0.1	0.1	–	–	–	–
Capital Equipment	–	<0.1	<0.1	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.4	0.1	0.1	0.1	–	–	–	–
Direct Personnel	2.6	1.0	0.8	0.8	–	–	–	–
Arms Control and Nonproliferation (GJ)								
Operating	4.7	7.8	10.4	11.1	11.1	11.1	11.1	11.1
Capital Equipment	–	0.3	0.4	0.2	0.2	0.2	0.2	0.2
Construction	–	–	–	–	–	–	–	–
Total	4.7	8.1	10.8	11.3	11.3	11.3	11.3	11.3
Direct Personnel	24.4	23.9	34.0	35.6	35.6	35.6	35.6	35.6
Emergency Preparedness (NB)								
Operating	0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	–	–	–	–	–	–	–
Direct Personnel	0.1	–	–	–	–	–	–	–
Intelligence (NT)								
Operating	0.3	0.3	0.3	0.2	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.3	0.3	0.3	0.2	0.1	0.1	0.1	0.1
Direct Personnel	2.3	2.5	1.4	0.8	0.8	0.8	0.8	0.8

Table XII.10 Nonproliferation and National Security: Resources by Subprogram (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Emergency Management (ND)								
Operating	–	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	–	0.8	0.5	0.3	0.3	0.3	0.3	0.3
Total Nonproliferation and National Security								
Operating	8.2	10.3	12.9	13.6	13.4	13.4	13.4	13.4
Capital Equipment	0.3	0.3	0.4	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	8.5	10.6	13.3	13.8	13.6	13.6	13.6	13.6
Direct Personnel	41.3	39.8	46.3	47.0	46.2	46.2	46.2	46.2

Table XII.11 Environmental Management: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Environmental Restoration and Waste Management — Defense (EW)								
Operating	40.8	30.7	28.9	24.1	24.1	24.1	24.1	24.1
Capital Equipment	3.1	1.2	1.1	0.5	0.5	0.5	0.5	0.5
Construction	–	–	–	–	–	–	–	–
Total	43.9	31.9	30.0	24.6	24.6	24.6	24.6	24.6
Direct Personnel	188.4	180.4	143.0	127.2	127.2	127.2	127.2	127.2
Environmental Restoration and Waste Management — Non-Defense (EX)								
Operating	29.3	25.2	28.6	27.7	25.3	25.3	25.3	25.3
Capital Equipment	0.8	0.1	0.2	–	–	–	–	–
Construction	3.6	1.3	0.4	2.8	–	–	–	–
General Plant Projects	0.4	0.4	0.3	0.3	0.3	0.1	–	–
Total	34.1	27.0	29.5	30.8	25.6	25.4	25.3	25.3
Direct Personnel	154.6	147.8	128.5	125.5	122.6	122.6	122.6	122.6
Total Environmental Management								
Operating	70.1	55.9	57.5	51.8	49.4	49.4	49.4	49.4
Capital Equipment	3.9	1.3	1.3	0.5	0.5	0.5	0.5	0.5
Construction	3.6	1.3	0.4	2.8	0.0	0.0	0.0	0.0
General Plant Projects	0.4	0.4	0.3	0.3	0.3	0.1	0.0	0.0
Total	78.0	58.9	59.5	55.4	50.2	50.0	49.9	49.9
Direct Personnel	343.0	328.2	271.5	252.7	249.8	249.8	249.8	249.8

Table XII.12 Environment, Safety, and Health: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Environment, Safety, and Health (HA)								
Operating	3.1	2.4	2.3	2.3	2.3	2.3	2.3	2.3
Capital Equipment	<0.1	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	3.1	2.4	2.3	2.3	2.3	2.3	2.3	2.3
Direct Personnel	29.0	15.8	15.2	15.1	15.1	15.1	15.1	15.1
Nuclear Safety Policy (HP-01)								
Operating	0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	–	–	–	–	–	–	–
Direct Personnel	0.2	–	–	–	–	–	–	–
Security Evaluations (HS)								
Operating	1.4	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.4	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Direct Personnel	7.8	4.8	5.7	5.7	5.5	5.3	5.3	5.3
Nuclear Safety Oversight (NS-02)								
Operating	–	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	–	0.5	0.6	0.6	0.7	0.7	0.7	0.7
Total Environment, Safety, and Health								
Operating	4.6	3.7	3.6	3.6	3.6	3.6	3.6	3.6
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	4.6	3.7	3.6	3.6	3.6	3.6	3.6	3.6
Direct Personnel	37.0	21.1	21.5	21.4	21.3	21.1	21.1	21.1

Table XII.13 Civilian Radioactive Waste Management ($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Waste Management System (DB)								
Operating	3.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	3.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	15.8	4.1	0.6	0.5	0.5	0.5	0.5	0.5

Table XII.14 Policy, Planning, and Program Evaluation: Resources by Subprogram ($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
International Policy Studies (NA-02)								
Operating	–	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.7	1.1	1.3	1.3	1.3	1.3	1.3	1.3
Planning and Analysis (PE-01)								
Operating	0.6	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.6	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	4.5	2.0	1.3	1.0	1.0	1.0	1.0	1.0
Office of Environmental Analysis (PE-04)								
Operating	1.0	0.3	0.6	0.6	0.6	0.6	0.6	0.6
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.0	0.3	0.6	0.6	0.6	0.6	0.6	0.6
Direct Personnel	5.7	4.3	5.0	4.5	4.5	4.5	4.5	4.5
Total Policy, Planning, and Program Evaluation								
Operating	1.6	0.8	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	1.6	0.8	1.0	1.0	1.0	1.0	1.0	1.0
Direct Personnel	10.9	7.4	7.6	6.8	6.8	6.8	6.8	6.8

Table XII.15 Economic Impact and Diversity ($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Minority Economic Impact Program (WA-50)								
Operating	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	3.6	2.2	2.0	2.0	2.0	2.0	2.0	2.0

Table XII.16 Energy Information Administration ($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
National Energy Information System (TA)								
Operating	0.1	<0.1	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	–	–	–	–	–	–	–
Direct Personnel	1.2	0.5	–	–	–	–	–	–

Table XII.17 Work for Other DOE Contractors ($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Operating	17.2	18.0	19.5	19.5	19.5	19.5	19.5	19.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	17.2	18.0	19.5	19.5	19.5	19.5	19.5	19.5
Direct Personnel	36.3	36.3	36.3	36.3	36.3	36.3	36.3	36.3
Transfer to Other DOE Contractors	(5.3)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)

Table XII.18 Work for Sponsors Other than DOE ($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
NUCLEAR REGULATORY COMMISSION								
Office of Nuclear Regulatory Research								
Operating	7.5	10.5	10.4	9.0	9.0	8.7	8.7	8.7
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	7.5	10.5	10.4	9.0	9.0	8.7	8.7	8.7
Direct Personnel	26.5	36.7	35.5	30.5	30.1	29.0	24.6	24.6
Office of Nuclear Reactor Regulation								
Operating	0.4	0.3	0.3	0.2	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.4	0.3	0.3	0.2	0.1	0.1	0.1	0.1
Direct Personnel	1.7	1.3	1.3	1.2	1.0	1.0	1.0	1.0
Commission and Staff Offices								
Operating	<0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	0.1	–	–	–	–	–	–	–
Nuclear Material Safety and Safeguards								
Operating	<0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	0.1	–	–	–	–	–	–	–
Office of Administration								
Operating	<0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	0.1	–	–	–	–	–	–	–

Table XII.18 Work for Sponsors Other than DOE (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Executive Director for Operations and Staff Offices								
Operating	<0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	0.1	–	–	–	–	–	–	–
Total Nuclear Regulatory Commission								
Operating	7.9	10.8	10.7	9.2	9.1	8.8	8.8	8.8
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	7.9	10.8	10.7	9.2	9.1	8.8	8.8	8.8
Direct Personnel	28.6	38.0	36.8	31.7	31.1	30.0	25.6	25.6
DEPARTMENT OF DEFENSE								
Strategic Defense Initiative								
Operating	3.8	0.2	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	3.8	0.2	–	–	–	–	–	–
Direct Personnel	4.7	1.0	–	–	–	–	–	–
Advanced Research Projects Agency								
Operating	0.5	0.5	0.5	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.5	0.5	0.5	0.1	0.1	0.1	0.1	0.1
Direct Personnel	4.0	4.0	4.0	1.8	1.8	1.8	1.8	1.8

Table XII.18 Work for Sponsors Other than DOE (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
National Security Agency								
Operating	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1
Direct Personnel	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0
U.S. Air Force								
Operating	5.3	3.6	3.5	3.5	3.5	3.5	3.5	3.5
Capital Equipment	0.3	0.2	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	5.6	3.8	3.5	3.5	3.5	3.5	3.5	3.5
Direct Personnel	20.2	19.0	16.5	16.5	16.5	16.5	16.5	16.5
The Joint Staff								
Operating	5.6	2.0	1.0	0.8	0.8	0.8	0.8	0.8
Capital Equipment	0.2	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	5.8	2.0	1.0	0.8	0.8	0.8	0.8	0.8
Direct Personnel	27.0	12.0	8.0	5.0	5.0	5.0	5.0	5.0
U.S. Army								
Operating	16.8	12.0	13.0	13.0	13.0	13.0	13.0	13.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	16.8	12.0	13.0	13.0	13.0	13.0	13.0	13.0
Direct Personnel	71.8	55.0	55.0	52.0	52.0	52.0	52.0	52.0
U.S. Navy								
Operating	1.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	11.0	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Defense Nuclear Agency								
Operating	1.5	2.7	2.1	0.9	0.6	0.6	0.6	0.6
Capital Equipment	–	2.2	0.5	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.5	4.9	2.6	0.9	0.6	0.6	0.6	0.6
Direct Personnel	2.4	22.2	11.8	7.1	6.0	6.0	6.0	6.0

Table XII.18 Work for Sponsors Other than DOE (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
U.S. Marines								
Operating	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Secretary of Defense								
Operating	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	3.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total Department of Defense								
Operating	35.9	21.7	20.8	19.0	18.5	18.5	18.5	18.5
Capital Equipment	0.5	2.4	0.5	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	36.4	24.1	21.3	19.0	18.5	18.5	18.5	18.5
Direct Personnel	147.1	116.9	99.0	86.1	84.0	84.0	84.0	84.0
OTHER FEDERAL AGENCIES								
Environmental Protection Agency								
Operating	0.8	0.7	0.8	0.8	0.6	0.6	0.6	0.6
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.8	0.7	0.8	0.8	0.6	0.6	0.6	0.6
Direct Personnel	3.5	3.5	4.0	4.0	3.0	3.0	3.0	3.0
Arms Control and Disarmament Agency								
Operating	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Direct Personnel	1.7	0.7	0.7	0.8	0.4	0.4	0.4	0.4

Table XII.18 Work for Sponsors Other than DOE (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Federal Emergency Management Agency								
Operating	5.2	2.7	3.0	3.0	3.0	3.0	3.0	3.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	5.2	2.7	3.0	3.0	3.0	3.0	3.0	3.0
Direct Personnel	27.0	13.5	14.0	14.0	14.0	14.0	14.0	14.0
Department of State and International Atomic Energy Agency								
Operating	2.2	3.4	1.9	1.9	2.0	2.0	2.0	2.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	2.2	3.4	1.9	1.9	2.0	2.0	2.0	2.0
Direct Personnel	11.3	11.6	11.2	11.2	11.2	11.2	11.2	11.2
Agency for International Development								
Operating	0.4	0.1	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.4	0.1	–	–	–	–	–	–
Direct Personnel	1.3	0.3	–	–	–	–	–	–
Health and Human Services								
Operating	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Capital Equipment	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Construction	–	–	–	–	–	–	–	–
Total	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Direct Personnel	10.6	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Department of Transportation								
Operating	1.3	0.4	1.6	2.0	2.0	2.0	2.0	2.0
Capital Equipment	–	–	0.2	0.4	0.8	0.8	0.8	0.8
Construction	–	–	–	–	–	–	–	–
Total	1.3	0.4	1.8	2.4	2.8	2.8	2.8	2.8
Direct Personnel	3.0	5.0	8.0	9.5	9.5	9.5	9.5	9.5

Table XII.18 Work for Sponsors Other than DOE (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Department of Agriculture								
Operating	6.5	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	6.5	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Direct Personnel	16.0	16.0	15.5	15.5	15.5	15.5	15.5	15.5
Department of Commerce								
Operating	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
National Science Foundation[a]								
Operating	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Other Agencies								
Operating	4.5	2.7	2.7	3.2	3.3	3.4	3.4	3.4
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	4.5	2.7	2.7	3.2	3.3	3.4	3.4	3.4
Direct Personnel	21.6	12.2	13.1	14.8	15.0	15.0	15.0	15.0
Total Other Federal Agencies								
Operating	23.0	18.1	18.1	19.0	18.9	19.0	19.0	19.0
Capital Equipment	0.0	0.0	0.2	0.4	0.8	0.8	0.8	0.8
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	23.0	18.1	18.3	19.4	19.7	19.8	19.8	19.8
Direct Personnel	98.0	74.5	78.2	81.5	80.3	80.3	80.3	80.3

Table XII.18 Work for Sponsors Other than DOE (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
NONFEDERAL ORGANIZATIONS								
Electric Power Research Institute								
Operating	2.5	1.6	1.0	1.0	1.0	1.0	1.0	1.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	2.5	1.6	1.0	1.0	1.0	1.0	1.0	1.0
Direct Personnel	15.6	15.3	9.0	9.0	9.0	9.0	9.0	9.0
Gas Research Institute								
Operating	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Private Firms								
Operating	6.5	10.8	11.5	11.5	11.5	11.5	11.5	11.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	6.5	10.8	11.5	11.5	11.5	11.5	11.5	11.5
Direct Personnel	30.7	51.0	51.0	51.0	51.0	51.0	51.0	51.0
Universities and State and Local Governments								
Operating	1.0	0.6	0.4	0.4	0.4	0.4	0.4	0.4
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.0	0.6	0.4	0.4	0.4	0.4	0.4	0.4
Direct Personnel	8.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0
Total Nonfederal Organizations								
Operating	10.2	13.1	13.0	13.0	13.0	13.0	13.0	13.0
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	10.2	13.1	13.0	13.0	13.0	13.0	13.0	13.0
Direct Personnel	55.2	71.0	63.7	63.7	63.7	63.7	63.7	63.7

Table XII.18 Work for Sponsors Other than DOE (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
TOTAL WORK FOR SPONSORS OTHER THAN DOE								
Operating	77.0	63.7	62.6	60.2	59.5	59.3	59.3	59.3
Capital Equipment	0.5	2.4	0.7	0.4	0.8	0.8	0.8	0.8
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	77.5	66.1	63.3	60.6	60.3	60.1	60.1	60.1
Direct Personnel	328.9	300.4	277.7	263.0	259.1	258.0	253.6	253.6

[a]Funds supporting Argonne's participation in the Science and Technology Center for Research on Parallel Computation and the Science and Technology Center for High Temperature Superconductivity come from the National Science Foundation, through Rice University and the University of Illinois, respectively. These funds are included in the resource projections for universities and state and local governments.

Table XII.19 Funding by Assistant Secretarial Office ($ in millions BA, personnel in FTE)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
DOE WORK								
Table XII.3 — Nuclear Energy, Science and Technology								
Operating	100.5	95.9	98.6	98.5	99.3	102.4	102.4	102.4
Capital Equipment	1.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0
General Purpose Equipment	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Construction	3.4	1.7	2.2	0.0	0.0	0.0	0.0	0.0
General Plant Projects	1.6	0.0	2.0	1.0	1.2	2.5	2.5	2.5
Total	106.5	100.8	104.0	100.7	101.7	106.1	106.1	106.1
Direct Personnel	509.6	564.0	546.8	510.8	510.0	510.0	510.0	510.0
Table XII.4 — Energy Research								
Operating	166.1	174.7	184.8	220.8	222.6	224.0	224.0	224.3
Capital Equipment	11.8	18.5	15.5	23.9	23.6	24.0	24.0	24.0
General Purpose Equipment	2.2	2.0	3.5	3.7	3.9	4.1	4.3	4.5
Construction	83.0	7.8	5.3	0.0	0.0	0.0	0.0	0.0
General Plant Projects	2.2	4.3	7.0	7.4	7.8	8.2	8.6	9.0
Subtotal	265.3	207.3	216.1	255.8	257.9	260.3	260.9	261.8
Inventory	1.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2
Multiprogram Energy Laboratories — Facilities Support Program	5.0	7.3	4.8	9.4	0.3	0.0	0.0	0.0
Total Energy Research	271.5	214.7	221.0	265.4	258.4	260.5	261.1	262.0
Direct Personnel	990.4	994.1	995.5	1064.1	1068.6	1071.1	1071.1	1071.1
Table XII.5 — Science Education and Technical Information								
Operating	4.8	2.2	3.3	3.3	3.3	3.3	3.3	3.3
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	4.8	2.2	3.3	3.3	3.3	3.3	3.3	3.3
Direct Personnel	16.2	11.1	12.0	12.0	12.0	12.0	12.0	12.0
Table XII.6 — Energy Efficiency and Renewable Energy								
Operating	18.6	20.4	29.5	31.3	31.0	31.0	31.0	31.0
Capital Equipment	1.6	1.4	2.3	2.6	2.6	2.6	2.6	2.6
Construction	2.3	2.0	2.0	0.0	0.0	0.0	0.0	0.0
Total	22.5	23.8	33.8	33.9	33.6	33.6	33.6	33.6
Direct Personnel	108.7	111.2	119.6	130.7	128.7	128.7	128.7	128.7

Table XII.19 Funding by Assistant Secretarial Office (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Table XII.7 — Fossil Energy								
Operating	6.4	5.1	5.4	5.5	5.5	5.5	5.5	5.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	6.4	5.1	5.4	5.5	5.5	5.5	5.5	5.5
Direct Personnel	54.7	37.4	30.3	30.4	30.4	30.4	30.4	30.4
Table XII.8 — Fissile Materials Disposition								
Operating	0.6	0.9	1.0	1.2	1.2	1.2	1.2	1.2
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	0.6	0.9	1.0	1.2	1.2	1.2	1.2	1.2
Direct Personnel	1.2	4.8	5.3	6.1	6.1	6.1	6.1	6.1
Table XII.9 — Defense Programs								
Operating	1.3	2.1	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	1.3	2.1	0.8	0.8	0.8	0.8	0.8	0.8
Direct Personnel	12.0	18.0	4.6	3.5	3.5	3.6	3.6	3.6
Table XII.10 — Nonproliferation and National Security								
Operating	8.2	10.3	12.9	13.6	13.4	13.4	13.4	13.4
Capital Equipment	0.3	0.3	0.4	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	8.5	10.6	13.3	13.8	13.6	13.6	13.6	13.6
Direct Personnel	41.3	39.8	46.3	47.0	46.2	46.2	46.2	46.2
Table XII.11 — Environmental Management								
Operating	70.1	55.9	57.5	51.8	49.4	49.4	49.4	49.4
Capital Equipment	3.9	1.3	1.3	0.5	0.5	0.5	0.5	0.5
Construction	3.6	1.3	0.4	2.8	0.0	0.0	0.0	0.0
General Plant Projects	0.4	0.4	0.3	0.3	0.3	0.1	0.0	0.0
Total	78.0	58.9	59.5	55.4	50.2	50.0	49.9	49.9
Direct Personnel	343.0	328.2	271.5	252.7	249.8	249.8	249.8	249.8

Table XII.19 Funding by Assistant Secretarial Office (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Table XII.12 — Environment, Safety, and Health								
Operating	4.6	3.7	3.6	3.6	3.6	3.6	3.6	3.6
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	4.6	3.7	3.6	3.6	3.6	3.6	3.6	3.6
Direct Personnel	37.0	21.1	21.5	21.4	21.3	21.1	21.1	21.1
Table XII.13 — Civilian Radioactive Waste Management								
Operating	3.0	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	3.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	15.8	4.1	0.6	0.5	0.5	0.5	0.5	0.5
Table XII.14 — Policy, Planning, and Program Evaluation								
Operating	1.6	0.8	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	1.6	0.8	1.0	1.0	1.0	1.0	1.0	1.0
Direct Personnel	10.9	7.4	7.6	6.8	6.8	6.8	6.8	6.8
Table XII.15 — Economic Impact and Diversity								
Operating	0.8	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	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	3.6	2.2	2.0	2.0	2.0	2.0	2.0	2.0
Table XII.16 — Energy Information Administration								
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	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0

Table XII.19 Funding by Assistant Secretarial Office (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Table XII.17 — Work for Other DOE Contractors								
Operating	17.2	18.0	19.5	19.5	19.5	19.5	19.5	19.5
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	17.2	18.0	19.5	19.5	19.5	19.5	19.5	19.5
Direct Personnel	36.3	36.3	36.3	36.3	36.3	36.3	36.3	36.3
TOTAL WORK FOR DOE PROGRAMS								
Operating	403.9	390.6	418.5	451.5	451.2	455.7	455.7	456.0
Capital Equipment	18.6	24.5	20.5	28.2	27.9	28.3	28.3	28.3
General Purpose Equipment	2.2	2.2	3.7	3.9	4.1	4.3	4.5	4.7
Construction	92.3	12.8	9.9	2.8	0.0	0.0	0.0	0.0
General Plant Projects	4.2	4.7	9.3	8.7	9.3	10.8	11.1	11.5
Subtotal	521.2	434.8	461.9	495.1	492.5	499.1	499.6	500.5
Inventory	1.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2
Multiprogram Energy Laboratories — Facilities Support Program	5.0	7.3	4.8	9.4	0.3	0.0	0.0	0.0
Total	527.4	442.2	466.8	504.7	493.0	499.3	499.8	500.7
TRANSFER TO OTHER DOE CONTRACTORS	(5.3)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)
Table XII.18 — WORK FOR SPONSORS OTHER THAN DOE								
Nuclear Regulatory Commission								
Operating	7.9	10.8	10.7	9.2	9.1	8.8	8.8	8.8
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	7.9	10.8	10.7	9.2	9.1	8.8	8.8	8.8
Department of Defense								
Operating	35.9	21.7	20.8	19.0	18.5	18.5	18.5	18.5
Capital Equipment	0.5	2.4	0.5	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	36.4	24.1	21.3	19.0	18.5	18.5	18.5	18.5

Table XII.19 Funding by Assistant Secretarial Office (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
Other Federal Agencies								
Operating	23.0	18.1	18.1	19.0	18.9	19.0	19.0	19.0
Capital Equipment	0.0	0.0	0.2	0.4	0.8	0.8	0.8	0.8
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	23.0	18.1	18.3	19.4	19.7	19.8	19.8	19.8
Nonfederal Organizations								
Operating	10.2	13.1	13.0	13.0	13.0	13.0	13.0	13.0
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	10.2	13.1	13.0	13.0	13.0	13.0	13.0	13.0
TOTAL WORK FOR SPONSORS OTHER THAN DOE								
Operating	77.0	63.7	62.6	60.2	59.5	59.3	59.3	59.3
Capital Equipment	0.5	2.4	0.7	0.4	0.8	0.8	0.8	0.8
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	77.5	66.1	63.3	60.6	60.3	60.1	60.1	60.1
TOTAL OPERATING FUNDING	475.6	451.3	478.1	508.7	507.7	512.0	512.0	512.3
TOTAL CAPITAL EQUIPMENT	19.1	26.9	21.2	28.6	28.7	29.1	29.1	29.1
TOTAL CONSTRUCTION	92.3	12.8	9.9	2.8	0.0	0.0	0.0	0.0
TOTAL INVENTORY	1.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2
TOTAL GENERAL PURPOSE EQUIPMENT	2.2	2.2	3.7	3.9	4.1	4.3	4.5	4.7
TOTAL GENERAL PLANT PROJECTS	4.2	4.7	9.3	8.7	9.3	10.8	11.1	11.5
TOTAL MULTIPROGRAM ENERGY LABORATORIES — FACILITIES SUPPORT PROGRAM	5.0	7.3	4.8	9.4	0.3	0.0	0.0	0.0
GRAND TOTAL LABORATORY FUNDING	599.6	505.3	527.1	562.3	550.3	556.4	556.9	557.8

Table XII.19 Funding by Assistant Secretarial Office (Cont.)

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
TOTAL PROPOSED PROJECTS								
TOTAL PROGRAM CONSTRUCTION	0.0	0.0	0.0	7.6	18.1	8.0	8.0	8.0
TOTAL MULTIPROGRAM ENERGY LABORATORIES — FACILITIES SUPPORT PROGRAM	0.0	0.0	0.0	1.1	13.7	15.2	22.6	27.5
GRAND TOTAL PROJECTED FUNDING	599.6	505.3	527.1	571.0	582.1	579.6	587.5	593.3

Table XII.20 Subcontracting and Procurement ($ in millions)

	FY 1994	FY 1995	FY 1996[a]
Subcontracts and Procurements from Universities	6.8	6.0	8.0
All Other Subcontracts and Procurements	239.3	209.0	191.0
Transfer to Other DOE Facilities	4.8	1.7	1.0
Total Subcontracts and Procurements	250.9	216.7	200.0

[a]Estimate.

Table XII.21 Small and Disadvantaged Business Procurement ($ in millions)

	FY 1994	FY 1995	FY 1996[a]
Procurements from Small and Disadvantaged Businesses	22.9	19.1	12.0
Percent of Annual Procurement	9.1	8.8	6.0

[a]Estimate.

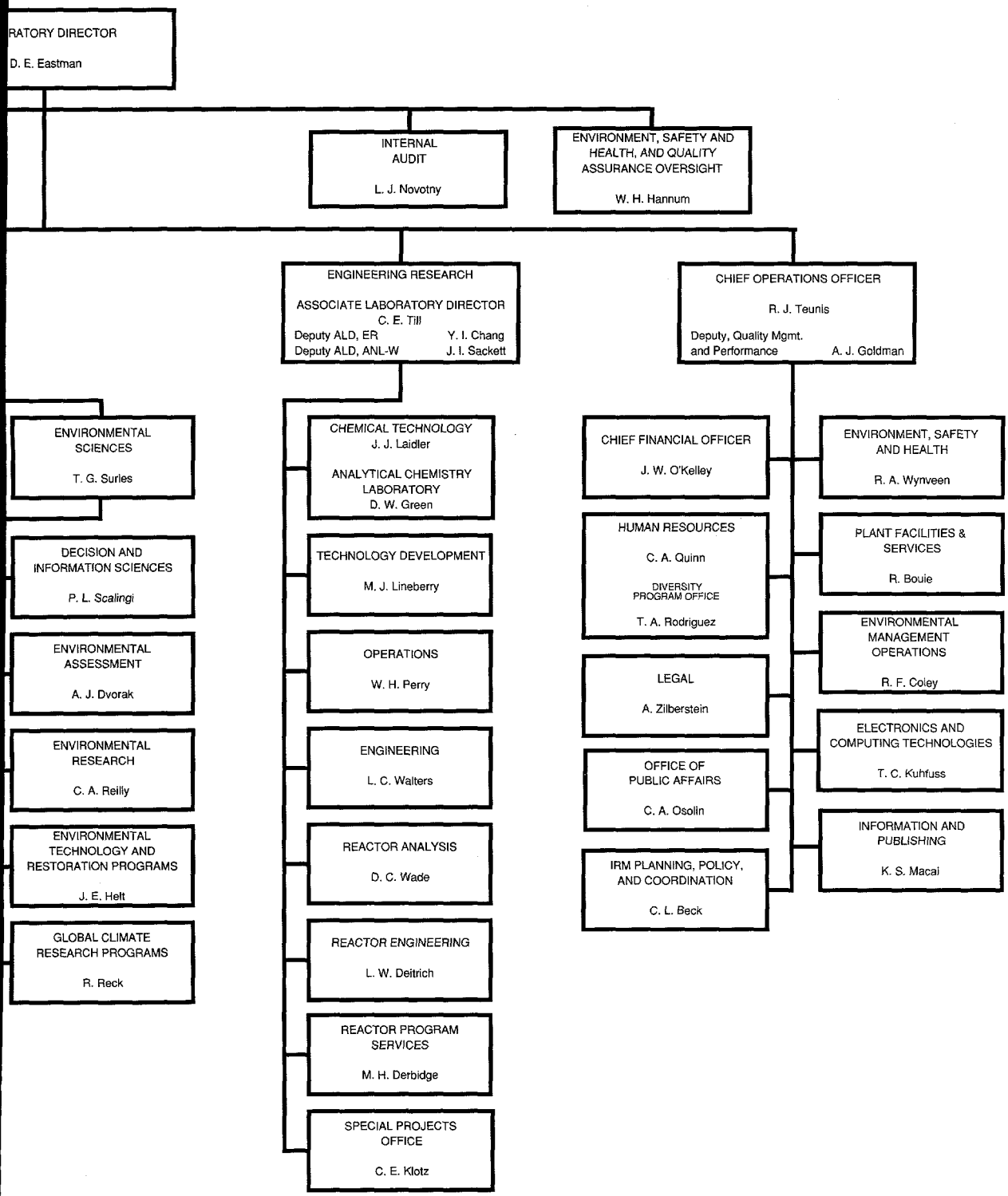
ARGONNE NATIONAL LABORATORY

ORGANIZATION CHART

Location	**9700 South Cass Avenue** **Argonne, Illinois 60439**
Operations Office	**Chicago**
Contract Number	**W-31-109-Eng-38**

Approved Dean E Eastman **July 15, 1996**
Director

IONAL LABORATORY



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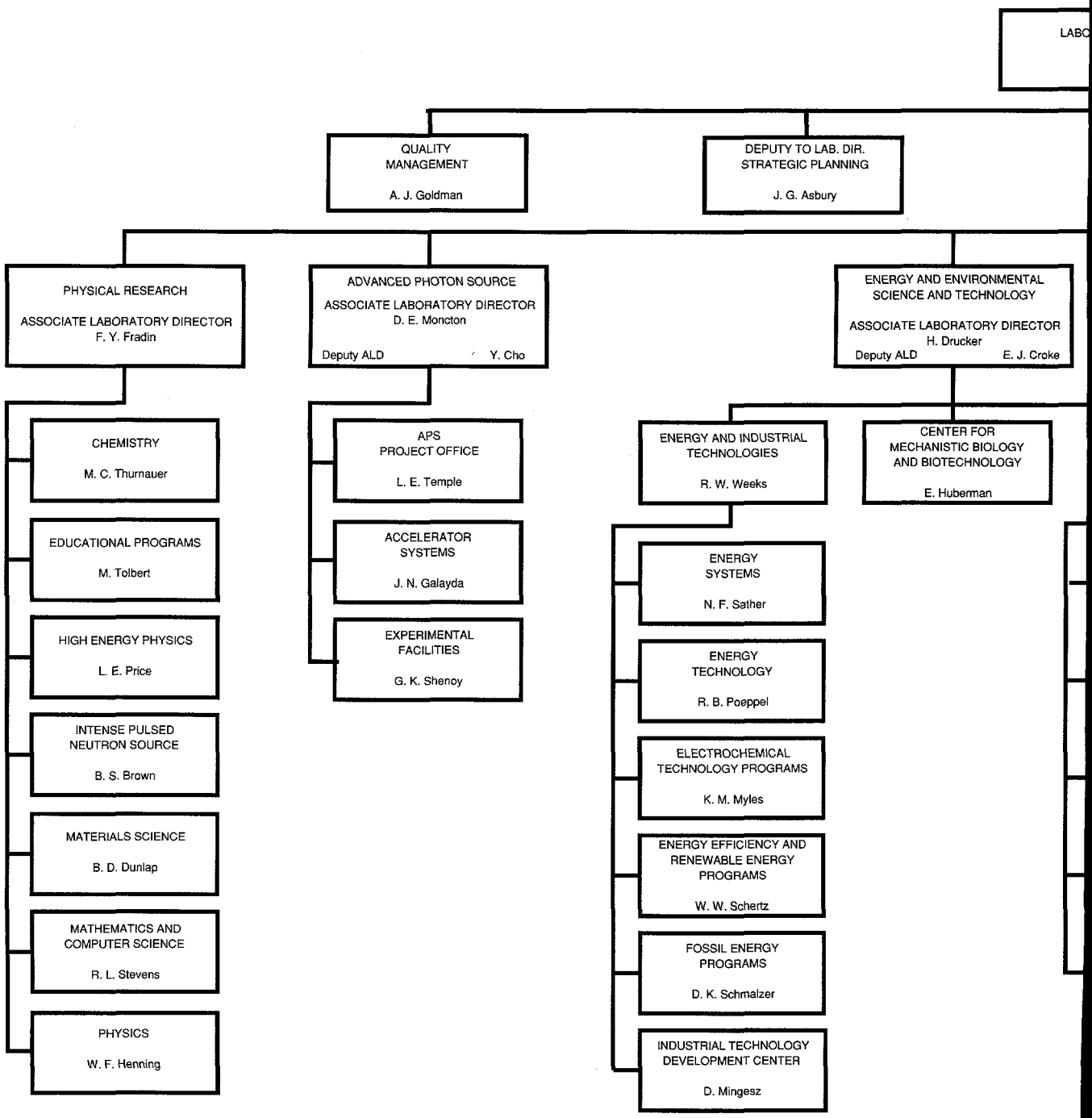
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