Argonne National Laboratory

INSTITUTIONAL PLAN: SUPPLEMENTS

FY 1998 - FY 2003

July 1997

Argonne National Laboratory

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REPORTING DATE

This July 1997 *Institutional Plan* was originally prepared in the early spring of 1997. It generally describes the activities and plans of Argonne National Laboratory as of that time. Thus, for example, financial data for FY 1997 are mid-year projections. In addition, a few selected revisions to the *Draft Institutional Plan* of May 1997 are included to reflect comments received and major shifts in plans.

DISCLAIMER

Contents

Supplement 1: 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 a number of initiatives that are closely linked to these programs. (See also the major initiatives described in Chapter IV in the lead volume.)

A. DOE Programs

1. Nuclear Energy, Science and Technology

a. Overview

Argonne's nuclear technology program includes (1) termination activities for the Experimental Breeder Reactor-II (EBR-II) and associated facilities and (2) nuclear technology R&D in the areas of electrometallurgical treatment of spent nuclear fuel; nuclear reactor safety for plants, both in the United States and in Russia and Eastern Europe; and nuclear technologies supporting the current generation of light-water reactors.

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 2000, in preparation for its 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 systems, 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. During the first quarter of FY 1997, unloading of core driver assemblies was completed. Secondary sodium has been drained completely from EBR-II.

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 and Environmental Laboratory. 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 of the sodium carbonate facility addition was completed in early 1996. After completion of construction, the facility is undergoing testing and readiness reviews for an anticipated start-up in March 1997.

Applications for required environmental permits have been completed or are under development. RCRA (Resource Conservation and Recovery Act) permits have been received both for the Sodium Processing Facility and for closure of EBR-II reactor systems. 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 has been to fabricate dummy assemblies to replace the driver and blanket assemblies removed from EBR-II. Current activities include (1) stripping plates from the Zero Power Physics Reactor containing highly enriched uranium and (2) casting the uranium to address a concern about the security of highly enriched uranium and to proceed with testing of waste forms from the FCF. Upon completion of these tasks, 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, as 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 electrorefining process. The FCF was prepared for a hot demonstration of electrometallurgical treatment of spent fuel from EBR-II, and irradiated fuel was successfully processed in June 1996. The environmental assessment for the facility was rewritten and was approved in May 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. Electrometallurgical Treatment

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 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, treatment of oxide spent fuel, development

of 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.

In mid FY 1997, Argonne's electrometallurgical treatment program is focused on three major activities: (1) treatment of EBR-II irradiated fuel; (2) demonstration of high-throughput electrorefining; and (3) separation of waste products from uranium and their incorporation into two waste forms potentially suitable for geologic disposal. Described more fully below are the nature of these three activities and the significant recent accomplishments on which they are based.

First, in an integrated research and process demonstration to be conducted in the FCF, irradiated fuel from EBR-II will be treated to neutralize its reactive characteristics (due to elemental sodium) and will be converted into a low-enriched uranium product, a ceramic waste, and a metal waste. This demonstration will be based on the following recent accomplishments:

- In early 1995, the four main process steps (element chopping, electrorefining, cathode processing, and casting) were installed in the FCF hot cells, and testing with depleted uranium began.
- In August 1995, FCF modifications were completed, and the facility was determined to be ready for operations with irradiated materials.
- In June 1996, new environmental documentation was completed for a limited process demonstration with EBR-II fuel. The scope was defined to answer specific questions developed by the National Research Council Committee on the Electrometallurgical Techniques for DOE Spent Fuel Treatment.
- In June 1996, the first EBR-II fuel assemblies were chopped and electrorefined.
- In August 1996, the first low-enriched uranium product was produced.
- Through May 1997, a total of 20 EBR-II fuel assemblies had been treated.

Second, for electrometallurgical treatment of DOE fuels that contain high masses of uranium (such as EBR-II blanket fuel assemblies) a new electrorefiner technology with higher capacity must be developed and demonstrated. This new high-throughput electrorefining technology will be demonstrated in FCF by using a new Mk-V electrorefiner. This demonstration will be based on the following recent accomplishments:

- In June 1994, the high-throughput electrorefining concept was tested at laboratory scale at Argonne-East.
- In January 1997, a new high-throughput electrorefiner capable of processing 150-kilogram uranium batches was installed in a glove box. This electrorefiner will test mechanical features and develop process parameters for the Mk-V electrorefiner that will treat EBR-II blanket fuel.
- In December 1996, the new Mk-V electrorefiner vessel was shipped to Argonne-West for assembly and out-of-cell testing. Installation in the FCF hot cell will begin in August 1997.

Third, during the electrometallurgical treatment processes, fission products are separated from uranium in preparation for incorporation into two waste forms potentially suitable for geologic disposal. Stainless steel components that are not dissolved in the electrorefining process are converted into a stainless steel-zirconium metal waste form. The majority of the fission products that accumulate in the electrorefiner salts are

processed into a ceramic waste containing zeolite. Completion of this activity will be based on the following recent accomplishments:

- In January 1995, initial corrosion tests and leaching tests showed that the metal waste would retain radioactive materials for geologic disposal.
- In July 1995, metal waste samples with nonradioactive fission product elements were cast in preparation for accelerated degradation tests. In May 1997, long-term corrosion tests were initiated. Resulting data will support evaluations of repository performance.
- In March 1996, metal waste samples were cast and tested with plutonium spikes. The tests showed that the metal waste could handle trace amounts of plutonium remaining from the treatment processes.
- In February 1997, metal waste samples containing technetium (a key radioactive element affecting repository performance) were cast, and characterization tests were initiated.
- In February 1997, the first process operations with radioactive metals from the EBR-II Spent Fuel Treatment Demonstration were initiated.
- In early 1992, electrorefiner salts with nonradioactive materials were incorporated into a ceramic waste containing zeolite, thereby proving basic process concepts.
- In December 1995, ceramic waste equipment built with current methods produced the first ceramic waste samples.
- In September 1996, baseline parameters were established for the ceramic waste process and waste compositions.
- During 1996, specific testing methods designed to provide characterization data on ceramic waste, for testing of its performance in a repository, were evaluated.
- In April 1997, the ceramic waste equipment for the EBR-II Spent Fuel Treatment Demonstration produced the first baseline ceramic waste samples with nonradioactive materials.
- In April 1997, baseline ceramic waste samples containing plutonium were produced, and characterization testing was initiated.

d. 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. Specific focuses are enhancement of and fuel cycle safety (for Soviet-designed plants in Russia and Eastern Europe, as well as U.S. plants) and development of D&D technology.

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 and 1996, when 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. The Laboratory is also developing a database of peer-reviewed assessments of material properties for use in safety analyses.

In July 1996, a Russian International Nuclear Safety Center was created. The Russian center and the DOE center at Argonne are collaborating on seven research projects, including database development, validation of safety codes, structural analysis, and studies of the thermophysical properties of materials.

Other evaluations of safety issues conducted for DOE by Argonne 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 developing a program to address the problems and risks associated with the deteriorating Chornobyl sarcophagus.

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

Argonne has a major role in DOE's Nuclear Risk Management Program. Laboratory personnel contribute to the effort to define, address, and resolve issues relating to severe accidents for advanced light-water reactors. For these issues, which 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 has a major role in developing DOE's Nuclear Energy Security program. Laboratory staff participate in research in three key areas: reactor operations technology, reactor materials research, and spent fuel minimization (in addition to the Nuclear Risk Management Program discussed above). In reactor operations technology, the Laboratory uses advanced computation to exploit improved phenomenological modeling, as well as capabilities in plant signal validation, diagnosis, transient management, and plant systems control. Research on reactor materials and spent fuel minimization exploits Argonne's capabilities to handle and characterize irradiated fuel and components.

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 promotes

extensive interactions between Argonne and the academic community through, for example, participation by students and faculty in the Laboratory's research.

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.

Argonne's theoretical and experimental investigations in high energy physics seek deeper understanding of the structure of matter at the most fundamental level. Required experiments usually employ large particle accelerators, but one major project is being carried out in an underground laboratory without use of accelerated particles. 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, the Intense Pulsed Neutron Source (IPNS), and the Basic Energy Sciences Synchrotron Radiation Center.

The Laboratory has completed construction of the Advanced Photon Source (APS), which is used for materials research and many other applications across an extraordinarily broad range from basic science to developmental engineering. Like earlier Argonne facilities, the APS serves 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, the photochemical energy sciences, chemical dynamics in the gas phase, metal cluster chemistry, photoionization-photoelectron spectroscopy, coal chemistry, the separation science and chemistry of the heavy elements, atomic physics, fluid catalysis, and advanced battery research.

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 newly established Center for Computational Science and Technology offers a massively parallel IBM SP computer and a "CAVE" virtual reality environment for large-scale calculations.

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

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 first-wall/blanket/shield 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 operation with liquid lithium for these tests.

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 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. The Laboratory continues to develop lithium ceramics for tritium production. Argonne is also 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.

c. Biological and Environmental Research (KP)

Argonne's human health and environmental research program encompasses studies in life sciences (KP-11) and environmental processes (KP-12). These studies include investigations in the general areas of molecular and cellular biology, DNA sequencing, biophysics, detector technology, statistical studies of health effects on animal populations, atmospheric science, microbiology, and ecology.

Life Sciences (KP-11)

Argonne's studies in the life sciences include work in structural biology, molecular biology, genome sequencing, and health effects.

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.

Integrated structural and solution studies elucidate chaperone-assisted protein folding.

Argonne operates a national user facility for structural biology at the APS. The Structural Biology Center uses 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.

In a study simulating enzyme reactions, Argonne has devised a unique computational method that combines quantum mechanical and molecular modeling schemes and uses fast, semi-empirical computational methods on massively parallel computers. Methods of this power and capacity will allow data gathered from synchrotron studies at the Structural Biology Center to be related to the fundamental structures of the system, possibly even for time-dependent phenomena.

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 fold at such high temperatures. The heat shock proteins, which are found in all organisms, are being studied; these proteins have been implicated in fundamental cellular processes and have relevance to treating 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. 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. Another project is developing the technique of "modular primer walking," which eliminates the primer synthesis step needed in conventional sequencing by primer walking.

Argonne's health effects research investigates 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 biostatistical research involves studying mortality in populations from a biological perspective, seeking common patterns of mortality between species, studying how aging-related mortality is modified by exposure to radiation, and developing mathematical models to predict age-specific mortality risks in humans from the mortality patterns observed in laboratory animals. These studies involve data generated by computer simulation, data on humans from the National Center for Health Statistics, and a large collection of mortality data from studies on laboratory animals. This research is intended to provide a deeper understanding of why organisms die and why they die when they do.

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 identifying genes important in radiosensitivity. Sensitive assays for gene expression using technology provided by Argonne's genome program 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.

Environmental Processes (KP-12)

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

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 the state of the global environment.

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.

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.

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.

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.

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.

For DOE's Program for Ecosystem Research, Argonne is conducting laboratory and field studies on the mechanisms that control mycorrhizal symbiosis in plant-soil systems within a changing global environment. The objective is to determine whether a primary mechanism controlling the mycorrhizal fungus 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 production and use of energy that are both effective and environmentally protective. 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.

A prototype user facility, focusing on studies of the planetary boundary layer, is being developed in southern Kansas (within the Cloud and Radiation Testbed [CART] site of the DOE ARM Program). Experiments began in 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 S1.1.

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 environmental impact from the tasks reviewed in 1992.

Table S1.1 Argonne National Atmospheric Observatory ($ in millions BA; personnel in FTE)

	FY97	FY98	FY99	FY00	FY01	FY02	FY03
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

d. High Energy Physics Research (KA)

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 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 determining proton structure and for hadronic final states. 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. At present, Argonne, in collaboration with U.S. universities, is adding 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. The 1992-1996 data permit more 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 is building several components for the upgrading of the CDF detector, which is presently underway in preparation for Run 2 of the Tevatron collider.

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 1999. The power of the detector to search for unusual nucleon decay modes, monopoles, and neutrino oscillations from cosmic ray event sources will increase as additional data are collected. 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.

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.

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 will build and instrument one of three major subsections of the hadronic calorimeter and will design and 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 detector at the LHC are summarized in Table S1.2. Funding is sought from the High Energy Physics Program (KA-04).

Table S1.2 ATLAS Detector at the LHC
($ in millions BA; personnel in FTE)

	FY97	FY98	FY99	FY00	FY01	FY02	FY03
Costs							
Operating	0.8	1.0	1.1	1.0	0.8	0.8	0.8
Capital Equipment	0.5	0.5	0.4	0.2	0.2	0.2	0.2
Construction	-	-	-	-	-	-	-
Total	1.3	1.5	1.5	1.2	1.0	1.0	1.0
Direct Personnel	6.1	7.1	8.5	7.5	6.0	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 underground 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.

Resources required for design and construction of the MINOS detector are summarized in Table S1.3. Funding is sought from the High Energy Physics Program (KA-04).

Table S1.3 MINOS Long-Baseline Detector
($ in millions BA; personnel in FTE)

	FY97	FY98	FY99	FY00	FY01	FY02	FY03
Costs							
Operating	0.7	1.0	1.1	1.1	0.8	0.8	0.8
Capital Equipment	0.3	0.6	1.0	1.0	0.6	0.4	0.4
Construction	-	-	-	-	-	-	-
Total	1.0	1.6	2.1	2.1	1.4	1.2	1.2
Direct Personnel	5.0	8.0	8.0	8.0	6.0	6.0	6.0

e. 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 the six experiments run in the first year of operation, two were led by Argonne spokesmen, and two others heavily involved Argonne researchers. Argonne staff lead four additional experiments that are expected to take data in the next two years.

A substantial portion of Argonne's work in medium energy physics has been devoted to developing a new technology for producing polarized hydrogen and deuterium targets for internal use in storage ring experiments. A collaboration between Argonne and a group of Soviet physicists at the Institute of Nuclear Physics in Novosibirsk pioneered some of these techniques at the 2.5-GeV VEPP-III electron storage ring. This work provided proof of principle for key elements of a broad North American-European experiment, titled HERMES. The objective of HERMES is to study the spin structure of the nucleon by using internally polarized hydrogen, deuterium, and helium targets at the HERA electron storage ring. HERMES has run very successfully for two years and is expected to continue for another five years. Argonne has primary responsibility for the hadron

identification systems in the HERMES spectrometer.

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.

Gammasphere, the national gamma-ray facility, will be transferred from Lawrence Berkeley National Laboratory to Argonne's ATLAS, starting in September 1998. The device will be coupled with the FMA for studies of the properties of nuclei at the proton-drip line and beyond. Further research with Gammasphere will exploit other unique capabilities, such as its ability to employ very heavy beams (lead-208 and uranium-236) and exceptional timing.

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 expanding as part of a broad-based program employing radioactive beams at a future exotic beam facility based on ATLAS. (See Section IV.B.)

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.

f. 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 investigates 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.

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, the electronic structure of complex materials, and magnetism. Strong collaboration with the Laboratory's computer science program aims 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. A new facility is being established at the APS to support *in situ* studies of materials prepared by metal-organic chemical vapor deposition.

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, the effects of neutron irradiation on reactor components and fuel materials, and the effects of radiation on properties such as amorphization.

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 also 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

Construction of the APS was completed in FY 1996, and operations were initiated. Accelerator systems and user support operations are committed to delivering the highest level of reliability and service to APS users. During FY 1996, the APS provided approximately 1,600 hours of beam time for users; the FY 1997 schedule doubles the amount of time available for research. The number of hours scheduled for users will continue to increase during the planning period, as the time required for installation and maintenance activities within the storage ring enclosure diminishes.

The APS provides dedicated technical, administrative, and safety support to the rapidly growing population of APS users. Fourteen collaborative access teams (CATs) presently occupy 20 of the 35 sectors possible at the APS. These teams pursue diverse scientific programs in materials sciences, chemistry and physics, structural biology, pharmaceutical research, and state-of-the-art applications of microimaging and microanalysis for geoscience, environmental science, and agriculture. At present, the CATs are engaged in various stages of construction, installation, testing, and use of the 40 X-ray beamlines available to them. All 40 beamlines are expected to become completely operational for research before the end of FY 1998. Several proposals to establish additional CATs are under consideration by the APS Program Evaluation Board.

Accelerator systems R&D at the APS is focusing on supporting day-to-day accelerator operations (in the near term), improving operations (in the mid term), and advancing the state of the art in producing synchrotron radiation (for the long term). Near-term efforts to improve reliability of accelerator operations involve (1) regular observation of systems performance, tracking problems, and remedies and (2) development of procedures for defining and scheduling routine maintenance. In FY 1997, the APS global feedback system will be commissioned, reducing beam size and opening angles by at least a factor of 10. Planned for FY 1998-FY 1999 are a number of performance upgrades to enhance beam current, position monitoring, and emittance and to improve radio frequency acceleration systems and power supply systems. Research on advanced concepts will address testing of self-amplified stimulated-emission (SASE) free-electron laser approaches, microfabrication of accelerator structures, production of slow positrons, and the use of intense X-ray beams to bond materials.

Experimental facilities research at the APS continues to focus on advancing X-ray beamline optics and instrumentation; on the design, fabrication, and testing of insertion devices with specialized capabilities; and on developing the scientific basis for implementing new X-ray research beamlines. The Synchrotron Radiation Instrumentation CAT, which is directed by APS, operates three sectors for studies of optics and instrumentation and is developing plans for a fourth sector. In FY 1997-FY 1999, this CAT will establish at the new sector — with collaborators from the Purdue X-ray physics group and the Australian user community — the capability to measure magnetic circular dichroism from 0.5 keV to 80 keV. Key to this advance is joint construction of a prototype helical undulator with scientists at the Budker Institute at Novosibirsk, Russia. APS scientists will also design and build an extra-long undulator for use in FY 1998 to demonstrate the SASE principle for wavelengths

of 50-100 nm. This device, with its required diagnostics, will be used to address (1) the transfer of coherence through beamline optics and (2) thermal problems anticipated in the use of nanosecond photon pulses from a free-electron laser. Also planned is exploration of other concepts for dedicated sources and instrumentation needed to implement specialized types of X-ray measurements, in order to use fully the remaining capacity of the APS.

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 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 1997, IPNS operated for 22 weeks under DOE sponsorship and for 2 weeks as part of the National Science Foundation's Science and Technology Center for High Temperature Superconductivity.

g. 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) the electrochemical and structural properties of electrodes and electrolytes in 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. A new study in this area is assessing the role of nonthermalized intermediates in high-energy chemistry. To develop the capability for research 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 recently began to study the fundamental radiation chemistry of radicals and radical ions of nitrogen oxides in homogeneous and heterogeneous systems. Theoretical investigation of the energetics of the radicals and their reaction pathways is planned. This research is closely coupled to the research proposed below in the initiative "Fundamental Chemistry of Radioactive Waste," which bears directly on the needs of DOE-Environmental Management.

Argonne's research in photochemical energy sciences seeks to understand the mechanisms of electron transfer and optimized charge separation in natural photosynthetic systems and 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 and X-ray scattering; X-ray absorption techniques; and ultrafast time-resolved optical spectroscopy), synthesis, and theory. Research recently begun aims to characterize nuclear reorganization inextricably coupled to the photochemistry associated with natural photosynthetic systems. 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 Computational 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, especially on bimetallic cluster systems. One particular future thrust will involve the study of unimolecular reactions on cluster surfaces in real time. Another will expand theoretical work aimed at formulating correlations between the structural, magnetic, and optical properties of clusters and will initiate studies on constrained 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 24,000 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 using toroid nuclear magnetic resonance techniques to study catalytic reaction chemistry *in situ* at high pressure and temperature. Plans for experimentation in supercritical water are closer to fruition, following the development of an all-metal chamber (with electrical connections on its exterior walls) capable of withstanding the corrosive environment associated with that medium. New research will continue to 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 develops and characterizes new separation processes and improved reagents applicable to environmental remediation 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 new classes of multifunctional extractants with enhanced selectivity for metal ions. In addition, the Laboratory plans to synthesize extended molecular structures in which molecular recognition occurs in two distinct stages, resulting in a precipitate that enables separation of metal ions.

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. Coordination chemistry research is linked with work in separations science, in order to expand investigations in areas likely to illuminate important issues relating to environmental restoration and waste management. 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 work will investigate the structure and heavy-element-encrypting properties of heteropolyanion clusters.

Argonne conducts fundamental experimental and theoretical studies to elucidate and resolve key issues that limit the performance of rechargeable lithium batteries used in nonautomotive applications. Argonne has initiated a search for materials suitable for novel or modified electrodes, at the same time seeking detailed understanding of the relationship between the structure and the electrochemical properties of the electrodes. One such study relates to preparation of carbon electrodes that exhibit superior performance as the negative electrode. The promising approach being 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. In addition, experimental and theoretical approaches, including neutron and X-ray scattering and *ab initio* molecular orbital theory, are being coupled to elucidate the structure, dynamics, and ion transport properties of lithium-polymer electrolytes. Further issues under study include 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. This combined approach will provide enhanced understanding of the behavior of electroactive materials and guidance in tailoring their structures.

Initiative: Fundamental Chemistry of Radioactive Waste

Argonne proposes a new integrated program in the fundamental chemistry of radioactive waste. This program of experimental and theoretical research will respond to a national need for fundamental knowledge of the chemistry underpinning technologies for the cleanup and disposal of radioactive waste, a need highlighted, for example, by "hydrogen burping" problems in DOE waste tanks. Further related issues requiring research include developing more efficient, cost-effective separation techniques for treating mixed waste, transuranic waste, and high-level waste; creating and characterizing new waste forms; oxide degradation processes that could limit some plutonium disposal options; and developing monitoring and characterizing sensor systems for research in waste management applications. Argonne is uniquely qualified to undertake this initiative through its core capabilities in chemical separations science, heavy-elements chemistry, radiation chemistry, and theoretical chemistry, as well as through its facilities for research with radioactive materials, including its cobalt-60 irradiation facility, the facility for actinide studies at the APS, and its megacurie and kilocurie hot cells.

Argonne is planning research on all of the issues relating to radioactive waste identified above. One initial effort involves investigating the chemistry of nitrogen oxides in homogeneous and heterogeneous systems, in connection with understanding the generation and reactivity of radiolytically produced nitrogen oxides in waste tanks. Nonlinear laser spectroscopy of actinide ions within representative glass matrices is being used to develop correlations between electronic energy levels and structural defects induced by microscopic radiation damage in glass waste forms. Use of X-ray absorption spectroscopy has shown that modifying a clay mineral surface by adding an organic coating is a good technique for sequestering uranium. Already planned is research leading toward relativistic quantum codes suitable for addressing issues in heavy-elements chemistry.

Building on these activities, Argonne plans a major research program with the following objectives:

- To study radiation chemistry in highly concentrated waste solutions and suspensions in order to improve understanding of the fundamental processes contributing to the radiolytic generation of chemical products in waste tanks
- To develop new separations procedures that can both provide the underlying technology to meet the challenges posed by mixed waste and continue contributing to the solution of high-level waste problems, such as removal of the fission product cesium, strontium, and technetium from high-level waste
- To investigate radiation effects in waste forms — especially bubble formation and transport in silicate glasses — and also develop new waste forms suitable for nuclear waste stabilization, including ceramic materials that are superior hosts for plutonium disposal
- To advance relativistic quantum code development sufficiently for simulation of systems containing a large number of atoms (including several that are heavy elements), thereby increasing the contribution of chemical theory to the radioactive waste management program (work supported in part as a Grand Challenge from the DOE Office of Computational and Technology Research, Mathematical Information and Computational Sciences Division)

Required resources for this initiative are summarized in Table S1.4. Funding is sought from the Chemical Sciences Program (KC-03) and the Environmental Management Science Program (EW-45).

Table S1.4 Fundamental Chemistry of Radioactive Waste ($ in millions BA; personnel in FTE)

	FY97	FY98	FY99	FY00	FY01	FY02	FY03
Costs							
Operating	1.3	2.4	3.6	4.0	4.0	4.0	4.0
Capital Equipment	-	0.3	0.4	0.5	0.5	0.5	0.5
Construction		-	-	-	-	-	-
Total	1.3	2.7	4.0	4.5	4.5	4.5	4.5
Direct Personnel	5.2	9.6	14.4	16.0	16.0	16.0	16.0

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.

This new accelerator will be designed to be user friendly, allowing establishment of a pulse radiolysis user facility serving researchers from both inside and outside Argonne. Funding is sought from the Chemical Sciences Program (KC-03). Required resources are summarized in Table S1.5.

Table S1.5 Linear Accelerator Upgrade — Ultrafast-Pulse Radiolysis Facility ($ in millions BA; personnel in FTE)

	FY97	FY98	FY99	FY00	FY01	FY02	FY03
Costs							
Operating	-	-	-	-	-	-	-
Capital Equipment	-	-	-	-	-	-	-
Construction	-	-	3.0	0.4	-	-	-
Total	-	-	3.0	0.4	-	-	-
Direct Personnel	-	-	1.0	1.0	-	-	-

h. Atomic, Molecular, and Optical Physics (KC-03)

The primary goal of Argonne's program in atomic, molecular, and optical physics is to

establish a fundamental understanding of how X-rays interact with atoms and molecules. Enabling studies use two unique facilities at the Laboratory: the APS and ATLAS. The APS provides intense, high-brilliance, polarized, tunable X-ray pulses that for the first time allow comprehensive studies of the structure and dynamics of isolated atoms and molecules at "atomic" length scales. Studies planned for the APS will investigate photoprocesses in prototypical systems in the range of hard X-rays and will provide a fundamental basis for the X-ray diagnostics used in other disciplines, such as Compton scattering studies of electron momentum distributions in materials, X-ray diffraction studies of large molecules, magnetic scattering studies of materials, and investigations of core-hole shifts in complex chemical environments. The study of atomic structure in few-electron systems at intermediate Z values, as planned at ATLAS, provides guidance and motivation for theoreticians working on the relativistic many-body problem in the regime where both electron correlation and relativistic and quantum electrodynamic effects are simultaneously important. The development of sophisticated detector technology required for the basic APS and ATLAS programs will further enable the examination of atoms under extreme conditions (such as intense fields provided by a laser) with an X-ray probe and the study of nonlinear optical interactions.

i. 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.

j. 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 assessment reports for Congress.

k. Advanced Energy Projects (KJ-03)

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

The fourth project will 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 titanium dioxide by using various chelating agents to enhance the redox properties of titanium dioxide 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 the future, Argonne plans to 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.

l. Mathematics and Computer Science (KJ-01)

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 applied computational 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 and worldwide 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. Computational chemistry studies point toward commercial applications involving environmental restoration and waste management, combustion, and chemical processing.

Essential to all this work is Argonne's Center for Computational Science and Technology, which features a massively parallel IBM SP computer. Via advanced networks, this facility is also available to outside collaborators.

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 several universities and national laboratories 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 immersive virtual reality environments, Argonne is exploring new approaches to collaborative science and technology applications.

m. Laboratory Technology Research Program (KJ-02)

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.

The ER-LTR program has three major elements: (1) mortgages of existing projects, (2) quick-response mechanisms, and (3) laboratory partnerships (multiyear cooperative R&D agreements [CRADAs]). Quick-response mechanisms — including personnel exchanges, small CRADAs, technology maturation projects, and technical assistance — address specific, near-term needs of industry and provide immediate results. The following types of quick-response mechanisms are used:

- Personnel exchanges allow Laboratory scientific staff to work collaboratively with their industrial and academic counterparts to share ideas, processes, cultures, and techniques. From the program's inception in 1991 to January 31, 1997, Argonne funded 23 such exchanges. The maximum level of funding is $50,000.

- Quick-response CRADAs are cooperative R&D arrangements, primarily with small businesses, focused on near-term technology applications. The funding maximum is $100,000 for a project of one year or less. Twenty-six such projects have been approved since the program began in 1991.

- Technology maturation projects are designed to move Laboratory technologies with commercial potential to a point where industry may engage in cooperative research or license the technology. The maximum funding level is $100,000, for a performance period of one year or less. Argonne has approved eight such proposals.

- Technical assistance projects provide small businesses with a means of quickly solving immediate technical problems. Assistance is limited to $5,000 per project. The problems addressed arise frequently throughout the year and tend to be particularly thorny or troublesome for the small business. To date, 61 projects have been approved.

"Laboratory partnerships" (formerly called multiyear CRADAs) involve cooperative R&D under a formalized industry-laboratory agreement. These arrangements involve well-defined, formally approved project plans to transfer Laboratory technologies to the industrial partner(s), generally with the dual goals of helping the partner and strengthening the Laboratory program. In more specific terms, these cooperative projects (1) enhance a specific Laboratory core capability that directly serves one or more of DOE's four mission areas (energy, environment, science and technology, and national security); (2) have high technical merit, matching unique capabilities of all the partners so that the investment of each is leveraged; (3) enable industry to perform precommercial research that alone it would be unable to undertake; and (4) meet specific industry needs for enhanced competitiveness to create new jobs or retain established jobs. Laboratory partnerships, which may not exceed $300,000 in annual DOE funding, are designed to provide three years of funding prior to demonstration or implementation by industry or the Laboratory. To date, 31 laboratory partnerships have been approved.

Because of a drastic decrease in federal support for the ER-LTR program, Argonne's funding for FY 1997 is approximately $3 million (down from $10.5 million in FY 1995, but up slightly from $2.5 million in FY 1996). Continuing projects will be supported from new funding or carryover. Initiation of two or three new projects is expected in FY 1997.

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. Argonne's technology center for the commercialization of superconductivity also plays an important role.

a. Systems Technology (EB-50)

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 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 Research Corp.). Under contracts with Tokyo Electric Power Co., the Laboratory has developed 2,000-ampere current 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 provides a focal point for interactions between Argonne scientists and engineers involved in industrial process design and product development. In FY 1996, researchers from American Superconductor Co., Intermagnetics General Corp., Illinois Superconductor, Commonwealth Research Corp., Plastronics, and Superconductive Components, Inc., participated in Center activities. 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.

b. 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.

Argonne has joined the "Chicago Partners in the American Dream," an alliance to create 5,000 new home ownership units in low-income Chicagoland communities. Argonne will assist in the application of technologies and techniques that increase energy efficiency. Argonne is also assisting the development of 500 energy-efficient row houses in a low-income neighborhood of Baltimore by using superinsulation measures defined in Illinois.

Argonne's broad capabilities in information technology are available to assist in urban redevelopment projects in at least two important ways. First, new Internet-based information retrieval technologies developed by Argonne for DOE (the Facility Profile Information Management System, for example) can be used by local communities for better consolidation, retrieval, integration, and evaluation of data concerning land use, which is currently a serious deficiency in many redevelopment programs. Second, new spatial analysis techniques that use geographic

information systems, decision analysis, and visualization technologies, such as the Dynamic Environmental Effects Model, can serve as planning tools for urban redevelopment.

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 that uses 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.

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).

c. 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. An important 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 Association; the Remanufacturing Industries Council, International; 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, U.S., 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 for recycling from obsolete automobiles and white goods after the metals have been removed. The process uses physical separation followed by chemical separation, and it significantly decreases the volume and cost of the waste disposal that is ultimately necessary. Cost-sharing arrangements for demonstrating a continuous process for recovering automotive polyurethane foam have been negotiated; plant start-up is expected in 1997. Also negotiated are cost-sharing

arrangements for commercial demonstration of a process for recovering acrylonitrile butadiene styrene (ABS), a high-value engineering plastic; plant start-up is targeted for early 1997.

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 esters from waste carbohydrates such as food processing waste or corn starch 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 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 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. Using a technology for the ethyl lactate process that it patented, Argonne is working on a replacement for many chlorinated solvents currently in use. The replacement is to be nontoxic, environmentally friendly, and competitive in cost. Negotiations with companies interested in commercializing the process are underway.

Argonne is working with a spin-off company, NTEC Ed Sep, in its development of new applications in the chemical industry for two-stage electrodialysis. The major focus is applications reducing pollution from processes being used by major manufacturers.

Under a cost-shared program with industry, Argonne developed state-of-the-art computer software that simulates the metal casting process. Industrial application of the software has produced castings at a significantly lower cost. Now Argonne is extending this work to modeling of the welding process, aiming at additional savings in production costs.

Argonne is supporting DOE with economic 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. Results include a forecast of the potential for improving U.S. energy efficiency in 2010 and years beyond.

Argonne is cooperating with the National Renewable Energy Laboratory (NREL), Idaho National Engineering and Environmental Laboratory (INEEL), 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; INEEL is examining the life cycle costs of potential products; and PNNL is mainly developing new products. Argonne, ORNL, NREL, and PNNL have entered into a CRADA with Applied Carbo Chemicals to commercialize the advances made in producing succinic acid.

The Laboratory 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.

The Laboratory is working with several major oil companies and Heat Transfer Research, Inc., to understand the mechanisms that control surface fouling. 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.

Argonne is conducting research in collaboration with the forest products industry in several areas, including the removal of nonprocess inorganics from process water, the application of neural networks to the pulping and paper-making processes, and the development of advanced drying equipment.

d. 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. 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.F) is being pursued in a three-year experimental study organized as a CRADA with the Association of American Railroads.

The Laboratory 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, using several types of alternatively fueled vehicles, became the first site in the nation to perform intensive "Level 2" data collection under the Alternative Fuels Motor Vehicle Act. The current 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., electro-plating 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.

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 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 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 FutureCar Challenge, a vehicle engineering research 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.

e. Federal Energy Management (WB)

The DOE Federal 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 has consolidated 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 Federal Energy Technology Center has been formed to consolidate the Morgantown and Pittsburgh Energy Technology Centers under a single management structure.

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, and AW)

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 emphasizes the development and evaluation of new processes that offer more cost-effective control of emissions. 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 has developed 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. To decrease costs by removing several pollutants in a single process, the Laboratory is studying techniques for converting mercury into soluble forms that can be captured in existing flue gas scrubbers. Argonne researchers have discovered beneficial reactions involving multiple pollutants (nitrogen oxides and mercury) that may lead to totally new commercial processes. 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.

The Laboratory'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 ceramic materials continues to emphasize development of nondestructive characterization methods. Current work focuses on methods of characterizing (1) density variations in ceramic composites for cleaning up hot gas streams and (2) *in situ* thermal properties of thermal-barrier coatings for advanced gas turbines. Research continues on the gaseous corrosion of metal alloys, with emphasis on (1) the development of protective scales and their effects on mechanical properties and (2) corrosion of thermal-barrier coatings.

The Laboratory is providing technical support for a field demonstration to evaluate technologies for the treatment 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. For the field demonstration, Argonne is developing plans, 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 four 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, 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 work on the coal and power systems business line for the Office of Planning and Environmental Analysis, Argonne focuses on air pollution issues as they affect the performance, cost, and market potential of advanced combustion systems. Current emphasis is on studying the role of nitrogen oxides from coal combustion in raising ozone concentrations in the eastern United States, through development and application of computer models of regional ozone formation. In other work, the potential of advanced coal technologies to improve air quality in the great Asian metropolitan areas is being studied through development of generic methodologies applicable to cities within the framework of Asia-wide regional air pollution transport models.

Initiative: Ion Transport Membranes for 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. DOE's Office of Fossil Energy has issued a solicitation for cost-shared proposals to advance this technology through a fully integrated unit at proof-of-concept scale. The total cost of this initiative is estimated to be $70 million; Argonne's research activities will require an estimated $3.8 million over five and one-half years (see Table S1.6).

Table S1.6 Ion Transport Membranes for Production of Synthesis Gas from Natural Gas
($ in millions BA; personnel in FTE)

	FY97	FY98	FY99	FY00	FY01	FY02	FY03
Costs							
Operating	-	0.6	0.6	0.6	0.6	0.6	0.3
Capital Equipment	-	0.1	0.4	-	-	-	-
Construction	-	-	-	-	-	-	-
Total	-	0.7	1.0	0.6	0.6	0.6	0.3
Direct Personnel	-	2.0	2.0	2.0	2.0	2.0	1.0

Argonne's contributions to this industry-led effort 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. Argonne's work on ion-conducting membranes includes development of proton-conducting ceramics to separate hydrogen — the ultimate clean fuel — from gaseous mixtures such as syngas, coal gas, and biogas.

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. Argonne assesses emergency preparedness exercises directed toward emergencies involving radiological, chemical, and hazardous materials. The Laboratory also develops and conducts training in the evaluation and control of emergency exercises, in public relations and media relations during emergencies, and in the operation of joint information centers. 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 nonproliferation, focusing on four major program areas: arms control and nonproliferation policy and technology, low-enrichment research reactor fuel, export control, and international safeguards. In addition, Argonne's expertise in emergency management is used by the Office of Emergency Management in support of its general oversight and policy-making role.

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; biologically engineered proteins for ultrasensitive detection of proliferation signatures; 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 proliferation 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.

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 translations for meetings in Moscow and for documents related to arms control and nonproliferation.

b. Low-Enrichment Research Reactor Fuel (GJ)

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 also assists designers of new research reactors by analyzing the safety, performance, and economic characteristics of reactors using such fuels. One joint study of this kind, with the China Institute of Atomic Energy, will begin late in FY 1997 to address the design of the new 60-megawatt China Advanced Research Reactor.

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 is developing and testing high-density fuels and will 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 has been the application of a technology based on uranium disilicide dispersion fuel that was 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. In March 1996, DOE funded Argonne to begin developing fuels with even higher uranium density, in order to convert existing reactors not adaptable to the disilicide fuel and to provide a fuel suitable for future advanced research reactors. The basic concept is to replace the uranium disilicide fuel powders with powders of gamma-phase-stabilized uranium alloys, which have much higher density. Screening irradiation tests will begin in the Advanced Test Reactor during the summer of 1997; first results are expected in the middle of FY 1998. Overall, a five-year program is envisioned.

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. Nuclear Transfer and Supplier Policy

For the Nuclear Transfer and Supplier Policy 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 Nonproliferation 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. Activities include assisting FSU countries 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. Argonne technical support has included MPC&A site surveys for selected nuclear facilities in Ukraine, Belarus, Latvia, Lithuania, Uzbekistan, Russia, 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.

e. Emergency Management (NN)

The DOE Office of Emergency Management has responsibility for general oversight and policy-making for all DOE emergency preparedness activities. Argonne's technical and analytical assistance to the office primarily involves technical review and analyses of plans, procedures, capabilities, and the various threats to effective emergency response. In addition, Argonne develops and conducts training in the evaluation and control

of emergency exercises, public information and media relations during emergencies, and operation of joint information centers.

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 CSEX (CeSium EXtraction) and SREX (StRontium EXtraction) process to extract cesium-137 and strontium-90 simultaneously from 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 treating hazardous, mixed, and radioactive materials in soil and groundwater.

Other work for OST involves analytical chemistry and characterization: (1) radioanalytical methods evaluation, (2) evaluation of the management and performance of analytical laboratories, and (3) field studies using a cone penetrometer. Argonne also supports the OST Subsurface Contamination Focus Group with environmental data integration at the Rocky Flats Environmental Technology Site for the reactive barriers project.

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 is hosting one of the first large-scale demonstrations in DOE's D&D focus area. 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 overall goal is to validate technologies for repetitive, reliable implementation; to acquire data on the performance of the technologies in the field; to assess the true costs of implementation; and to identify improvements in the technologies suitable for use within the DOE complex.

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. 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.

The Laboratory is also participating in the TechCon Program sponsored by the Office of Environmental Restoration, which seeks to bring application capabilities from the public and private sectors to serve high-priority DOE remediation needs. At the same time, Argonne monitors results from emerging technology demonstrations to determine their applicability at other DOE sites and facilitates applications 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. The Laboratory developed the technical basis for (1) DOE's "Recycle 2000" policy for recycling of radioactive scrap metal and (2) DOE's handbook on reuse and recycling as a way of controlling the release of nonreal property containing residual radioactivity.

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.

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 being demonstrated 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 and, in some cases, treatment 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 Martin 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. Over 200 drums have been characterized in this facility since 1994. Approximately 250 drums of waste will be characterized and repackaged in the facility each year through at least 2001. Characterization entails collecting gas and solid 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 container. Waste that does not meet acceptance criteria for the Waste Isolation Pilot Plant must be treated. In a joint project with Science Application International Corporation, Argonne is demonstrating a high-temperature thermal treatment technology for mixed waste, the plasma hearth process. A bench-scale facility demonstrating the process is located in the Transient Reactor Test Facility at Argonne-West. Radioactive testing, to be initiated early in 1997 and to continue at least into 1998, will provide essential data regarding how radioactive and hazardous contaminants — specifically plutonium, americium, and heavy metals regulated by the Resource Conservation and Recovery Act, such as cadmium, mercury, and lead — will behave in such a thermal treatment process.

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.

In response to the report of the Galvin Task Force and other recent recommendations, the Office of Environmental Management has established a Basic Science Program to develop and implement targeted long-term basic research that will help to solve environmental problems. The goal is "transformational" or breakthrough approaches to problems that will significantly reduce overall cleanup costs and risks to workers and the public. As part of the program, Argonne is being funded to address the following eight issues: (1) superconducting open-gradient magnetic separation for the pretreatment of radioactive or mixed-waste vitrification feeds; (2) nitrogen oxides in nuclear waste; (3) the use of sonication for in-well softening of semivolatile organic compounds; (4) stable isotopic investigations of *in situ* bioremediation of chlorinated organic solvents; (5) *in situ* spectroelectrochemical studies of radionuclide-contaminated surface films on metals and the mechanisms of their formation and dissolution; (6) ion and molecule sensors using molecular recognition in luminescent, conductive polymers; (7) the determination of transmutation effects in crystalline waste forms; and (8) investigation of microscopic radiation damage in waste forms by optically detected nuclear magnetic resonance and electron microscope imaging.

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. To accelerate characterization activities, the Laboratory has introduced adaptive sampling and analysis techniques. 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.

Environmental restoration at Argonne-East 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 the Illinois site. These facilities include the CP-5 Reactor, the JANUS reactor, the Zero Power Reactor, the Argonne Thermal Source Reactor, and other smaller facilities. At completion, the facilities will be available for unrestricted use. Argonne staff also support environmental restoration activities at other DOE sites, such as Brookhaven National Laboratory and the Oak Ridge Reservation. 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.

Argonne assists the DOE Office of Transportation, Emergency Management, and Analytical Services by evaluating safety analysis reports for spent-fuel casks and other radioactive transportation packaging systems. This project evolved from Argonne's long-established core competency in the development and evaluation of nuclear energy technology, as well as from a more recently developed competency in the assessment of transportation end uses. The Laboratory evaluates packaging designs to ensure that current safety regulations are met, conducts training in quality assurance, and develops public education materials.

8. Environment, Safety, and Health (HC)

For the Assistant Secretary for Environment, Safety, and Health, Argonne 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, as well as other materials containing residual radioactivity. 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.

Argonne recently completed an environmental impact statement for the Western Area Power Administration's (WAPA's) electric power marketing program for 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, recreation, 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 technical support to WAPA in the formulation of plans to protect affected resources.

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 and as the foundation for a future digital library. 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 via the World Wide Web.

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.

Initiative: Assessment and Management of Risk

Argonne continues to develop its 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 addresses 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 are risk management and related processes of communicating risks to decision makers and affected communities.

This initiative supports 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 S1.7. Funding is sought from the Environment, Safety, and Health Program (HC, HD) and also from the Environmental Management programs (EW and EX).

Table S1.7 Assessment and Management of Risk
($ in millions BA; personnel in FTE)

	FY97	FY98	FY99	FY00	FY01	FY02	FY03
Costs							
Operating	1.0	1.5	2.5	3.0	3.0	3.0	3.0
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	-	-	-	-	-	-	-
Total	1.1	1.6	2.6	3.1	3.1	3.1	3.1
Direct Personnel	5.1	7.1	11.0	12.0	12.0	12.0	12.0

9. Civilian Radioactive Waste Management (DB)

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.

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

In support of environmental policy-making by DOE, Argonne will be analyzing energy and environmental issues. Studies will address U.S. Environmental Protection Agency regulations that affect energy development and policy questions related to transportation. Argonne provides key support for assessments of atmospheric pollutants, 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 are analyzing nonpetroleum transportation fuels, vehicle technology, supplies of fuels, associated infrastructure needed, and the environmental effects of using compressed natural gas, methanol, ethanol, liquid propane gas, and electricity as transportation fuels. Argonne also supports analyses of transportation energy policies and related issues.

11. Economic Impact and Diversity (WA)

Argonne helps DOE's Office of Economic Impact and Diversity 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 various population groups, (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.

12. 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 (ORNL) as part of significant national programs under the Office of Conservation and Renewable Energy, the Office of Industrial Technologies (OIT), and the Office of Transportation Technologies (OTT). Funded by OIT, Argonne is developing nondestructive evaluation (NDE) methods of flash infrared imaging, elastic optical scattering, and air-coupled ultrasonics for continuous-fiber ceramic-matrix-composite (CFCC) materials; this work for the CFCC program is also to be applied to thermal-barrier coatings for the Advanced Turbine Systems project. Funded by OTT as part of the Heavy Vehicle Technology program, Argonne focuses on development of NDE methods for ceramics for diesel engines. These methods include high-resolution X-ray computed tomographic imaging ("CAT scans") and resonant ultrasound spectroscopy. For ORNL, as part of national programs funded by the Office of Energy

Research, Argonne is evaluating whether rapid prototyping technology can be used to fabricate functional ceramics directly.

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. In further support activities, Argonne is conducting experimental work on the design and synthesis of crown ethers specifically for waste separation.

Argonne is providing technical support to the DOE Idaho Operations Office for the Plutonium Focus Area and the National Spent Nuclear Fuel Program. This support includes experimental work, technical evaluation, and planning.

In support of the Oak Ridge Reservation and ORNL, Argonne is working on the design and application of centrifugal contactors to the process separation of radioactive elements from waste streams.

In support of DOE-Environmental Management, Argonne is collaborating on many projects with the DOE Nevada Operations Office and Sandia National Laboratories.

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 Chapter IV). From a national perspective, this "work for others" (WFO) allows Argonne's unique facilities and capabilities to be applied to U.S. R&D priorities.

The Laboratory's WFO strengthens resources available for DOE missions and programs and promotes development of specific energy and environmental technologies. 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 (1) growth rates of stress corrosion cracks and (2) the fatigue life of stainless and ferritic steels used in the reactor core, piping, and pressure vessel. Results from these studies are used by the NRC to ensure the structural integrity of plants as they age. The testing includes specimens from operating commercial reactors. Additional irradiations of stainless steels are performed in Norway's Halden test reactor to provide further systematic data on relationships between material composition and susceptibility to cracking after irradiation.

A comprehensive study of degradation in the steam generator tubing of nuclear power plants is underway. Critical areas being addressed include (1) evaluation of techniques used for in-service inspection of steam generator tubes and recommendations for improving the reliability and accuracy of those inspections, (2) validation and improvement of correlations for evaluating structural integrity and leakage of degraded steam generator tubes, and (3) validation and improvement of correlations and models for predicting degradation in aging tubes during operations. The studies focus on mill-annealed Alloy 600 tubing, but tests will also be performed on replacement materials such as thermally treated Alloy 600 and Alloy 690.

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

The NRC continues to use Argonne's broad expertise in severe-accident phenomena. An experimental study of the energetics of steam explosions resulting from interactions between water and molten core materials focuses on the possible extent of chemical augmentation of the energetics by metallic constituents in the core melt, particularly zirconium. Results will contribute to evaluation of the structural integrity of reactor vessels and their containments in severe accidents.

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. This work contributes to 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 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.

Argonne 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. The Laboratory also provides other support in the general area of managing the aging of nuclear systems. These activities are vital to Argonne's work in two of its major mission areas: energy technology and technical evaluation.

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 version of a mesoscale model originally developed by the National Center for Atmospheric Research and Pennsylvania State University. Argonne's parallel

version of the model has been running successfully in a semioperational mode on the high-performance computer network implemented by the Laboratory at Global Weather Central, located at Offutt Air Force Base in Omaha. Argonne's success in developing this test bed has motivated the Air Force to shift to a full-scale development program called the Global Weather Analysis and Prediction System.

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 better planning and simulation models and evaluating new or improved information management technologies. An important aspect of the work involves developing innovative uses of rapidly advancing graphics technologies to manipulate and analyze large databases. These Laboratory efforts take advantage of more than 15 years of experience in designing large engineering and scientific databases; developing new methods of representing data; and building and using knowledge bases, image exploitation, and data visualization. The work for J-8 also benefits from the availability of relevant advanced processors at Argonne's High-Performance Computing Research Facility, the Laboratory's extensive and diverse experience in applied decision analysis, and its experience in studying knowledge representation and applying expert systems.

Working with J-8, Argonne has greatly expanded its efforts to develop a modeling system for simulating and displaying environmental effects at 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 planning and decision support systems. Such systems integrate text management and data management technologies into a single platform for analyzing requirements for new acquisitions. In addition, the Laboratory is applying object-oriented techniques to mission planning. Associating image data with objects greatly enhances the quality of assessments. Argonne is using these tools to support the Joint Community in infrastructure assurance analyses and technical R&D evaluations.

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 intensely involved in the design and implementation of high-performance networks incorporating the latest switching technologies, to provide classified suites (both garrison and deployable) and unclassified suites with a high degree 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 to the J-8 Directorate, the Joint Staff, 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

For the Army Logistics Integration Agency, Argonne is part of a team developing the Distributed Intelligent Architecture for Logistics (DIAL), which will integrate logistics models into a distributed computing environment by using an architecture capable of expansion. A suite of independent software agents will manage communications and trigger tasks or events among distributed applications. The Laboratory will develop a functional model design and various software agents, implement and integrate a DIAL prototype, and plan and manage the project.

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. Argonne also is creating a knowledge-based air emissions reduction model to improve compliance decision making.

For the Waterways Experiment Station of the Army Corps of Engineers, Argonne has provided advanced visualization software to support field sampling; the Laboratory is currently a partner in the Groundwater Modeling System Program.

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.

For the Army Chemical and Biological Defense Command, Argonne assists in the development and analysis of restrictions regarding the land disposal of chemical agents and their by-products in the environment. Studies are coordinated with multiple environmental agencies within the Army and the state of Utah.

For the Edgewood Research, Development, and Engineering Center at Aberdeen Proving Ground, Argonne assists in assessments related to environmental compliance.

Argonne has undertaken studies of the environmental risks posed by active and former test ranges for the Army Test and Evaluation Command. Argonne is now conducting specific environmental restoration and compliance assessment studies at several installations of the Command (Dugway Proving Ground, Yuma Proving Ground, and Aberdeen Proving Ground).

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. Work addresses management of environmental information, 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.

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 development 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 supporting compliance and regulatory analyses for the Center. 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 (USADAC), the Laboratory is developing a data system for hazardous waste characterization to support environmental compliance related to the destruction of munitions and explosives at Army installations and to the reuse and recycling of components. In related efforts for the Army Industrial Operations Command, Argonne is developing a demilitarization planning and management system that incorporates the USADAC system and other information to improve the Army's ability to plan for cost-effective and environmentally sound demilitarization.

e. Defense Special Weapons Agency

As part of its arms control program, Argonne is developing verification procedures for the Defense Special Weapons 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 Special Weapons Agency's Arms Control Technology Program Office is developing technologies that will aid in the implementation of various arms control treaties. Effective verification of chemical arms control agreements, such as the recently signed Chemical Weapons Convention, requires protection of the health and safety of United Nations inspection teams. To make verification inspections safer, Argonne is developing a novel field-portable monitor for the selective determination of volatile organoarsenical agents at trace levels in ambient air.

The Laboratory is also assisting the Technology Applications Directorate with emergency preparedness reviews at civilian and military facilities.

f. Advanced Research Projects Agency

For the Advanced Research Projects Agency, Argonne is developing efficient algorithms and software for the symmetric and unsymmetric eigenvalue problem. In another project, the Laboratory is developing oligonucleotide microchip detectors that will detect and identify microbes; genes that code for protein toxins; and specific protein and chemical toxins.

3. Other Federal Agencies

a. Environmental Protection Agency

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 and Management, of which Argonne is a founding 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). Argonne staff serve as instructors for more than 75 courses, covering topics such as radiation protection, environmental monitoring, nuclear safety, and energy and environmental analysis. Training is conducted 25-28 weeks each year.

The IAEA, along with the State Department, has supported Argonne's development of analysis tools for decision making on energy and the environment. These tools are distributed to the ministries for energy and electric utilities in IAEA member states. In addition, Argonne staff participate in IAEA missions providing technical assistance in the recipient countries. Activities include training local experts to use the decision analysis tools developed at the Laboratory.

d. 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, and physiology.

The majority of these studies emphasize structure-function relationships or mechanisms underlying biological responses. One project focuses on the identification and characterization of genes that are induced in cultured cells following exposure to 60-hertz electromagnetic fields and other stress-inducing agents. The objective is to determine mechanisms for specific gene induction. In another study aimed at identifying new genetic regulatory elements, the Laboratory is using two-dimensional electrophoresis to investigate changes in protein expression resulting from chemical exposures. A database of protein changes is being created; species differences in response, as well as species-specific proteins, are being characterized.

Biophysical studies are addressing 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.)

e. 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.

f. Department of Agriculture

As part of an ongoing program for the Commodity Credit Corporation of the U.S. Department of Agriculture (CCC/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 CCC/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.

In other work for the USDA, the Laboratory is developing a decision support system to evaluate alternatives to certain pesticides under USDA review.

g. 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.

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 and several other universities and national laboratories, Argonne participates as a partner in the NSF-sponsored Science and Technology Center for Research on Parallel Computation.

h. 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 Institute

Argonne conducts research for the Electric Power Research Institute (EPRI) on topics related to the risk of a severe accident at a nuclear power plant. Major experiments were conducted to measure the release of fission products in aerosol form when concrete is attacked by molten core materials. Resulting data 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

Argonne is developing several programs with the Gas Research Institute (GRI) that involve the commercial development of a new corrosion probe, advanced techniques for geologic exploration, and research on cleaning up waste-water generated during natural gas production.

Argonne has also assisted GRI with the development of an Internet-based information system to disseminate R&D results.

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 the Association of American Railroads, BDM International, Braidwood Nuclear Power Station, the Chicago Manufacturing Center, CMS Rotational Dynamics, Eichrom Industries, Genencor International, General Motors, Kaiser Foundation, the National Center for Manufacturing Sciences, 3M, and Solar Turbines.

For the health care provider Kaiser Permanente, Argonne is developing a system to simulate the company's operations in southern California. Investigation of the effects of changes in health care policies on the company's membership will incorporate analyses of diseases (contraction, progression, treatment, and outcome), health care decisions of individuals, treatment decisions of the medical community, policy decisions of regulatory agencies, and related aspects of health care. The simulation system ultimately will provide information on the combined consequences of clinical, financial, administrative, and policy decisions for the membership's health and the cost and quality of their health care, allowing Kaiser Permanente to make better decisions. The simulation system includes more than 100 models and modules and can be employed at different levels of detail. At the heart of the system is a unique Argonne framework for coordinating new and existing models that originated in DOE-sponsored work and continues to be developed for the Joint Staff of the Department of Defense (see Section S1.C.2.c).

Argonne's work for private firms often grows out of industry-laboratory collaborative projects. 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 Program and the Office of Transportation Technologies. Industrial partners include the Low Emissions Partnership of the U.S. Council on Automotive Research, Spawr Industries, Laser Mechanisms, and U.S. Laser. Processes being pursued include high-power beam shaping and delivery, fiber optics, surface modification, 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, the Fusion Power Program, and decontamination and decommissioning of reactor systems.

d. State of Alabama

The Laboratory is initiating a series of studies for the Alabama Emergency Management Agency (AEMA) in support of six counties that adjoin a huge U.S. Army chemical stockpile, the Anniston Chemical Activity, which contains over 7% of the nation's unitary chemical-weapons agents. Construction of a high-temperature incinerator to destroy the stockpile is expected to begin soon. With support from the U.S. Army and the Federal Emergency Management Agency, AEMA is administering a program to enhance emergency preparedness against the risk of an accidental chemical release from continuing storage or the planned destruction of these chemical agents. Argonne's contribution will be to gather and analyze data on households in the area (constituting possibly the largest demographic survey ever undertaken in the United States outside the decennial census). AEMA and the six counties will use the information to assess how rapidly the population could evacuate in case of an accident and who might require special assistance, and therefrom to develop state-of-the-art emergency plans providing maximum protection to the public.

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, and the proceedings were published in 1996. A second workshop is planned for the fall of 1997.

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 developed a new prototype cryogenic resonator for the Nuclear Science Centre in New Delhi, India, and is now fabricating the first group of accelerating structures by following that design.

The Laboratory is collaborating with Egypt's Cairo University to establish there a state-of-the-art Center for Environmental Hazard Mitigation. This five-year project will address Egyptian environmental problems such as urban encroachment onto the fertile lands of the Nile Delta, sea shoreline erosion, and air and water pollution. Also being evaluated are the environmental impacts of the Salam Canal, the Toshka Depression, and other new development projects in Egypt.

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. Recently 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.

Supplement 2: 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 and Environmental 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 Advanced Photon Source (APS), the Laboratory's newest and largest user facility; 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. The Alpha-Gamma Hot Cell Facility supports examinations of materials for major Laboratory programs. Argonne-East also houses a full spectrum of administrative and technical support organizations, as well as the DOE Chicago Operations Office and the New Brunswick Laboratory, both of which use facilities operated and maintained by Argonne.

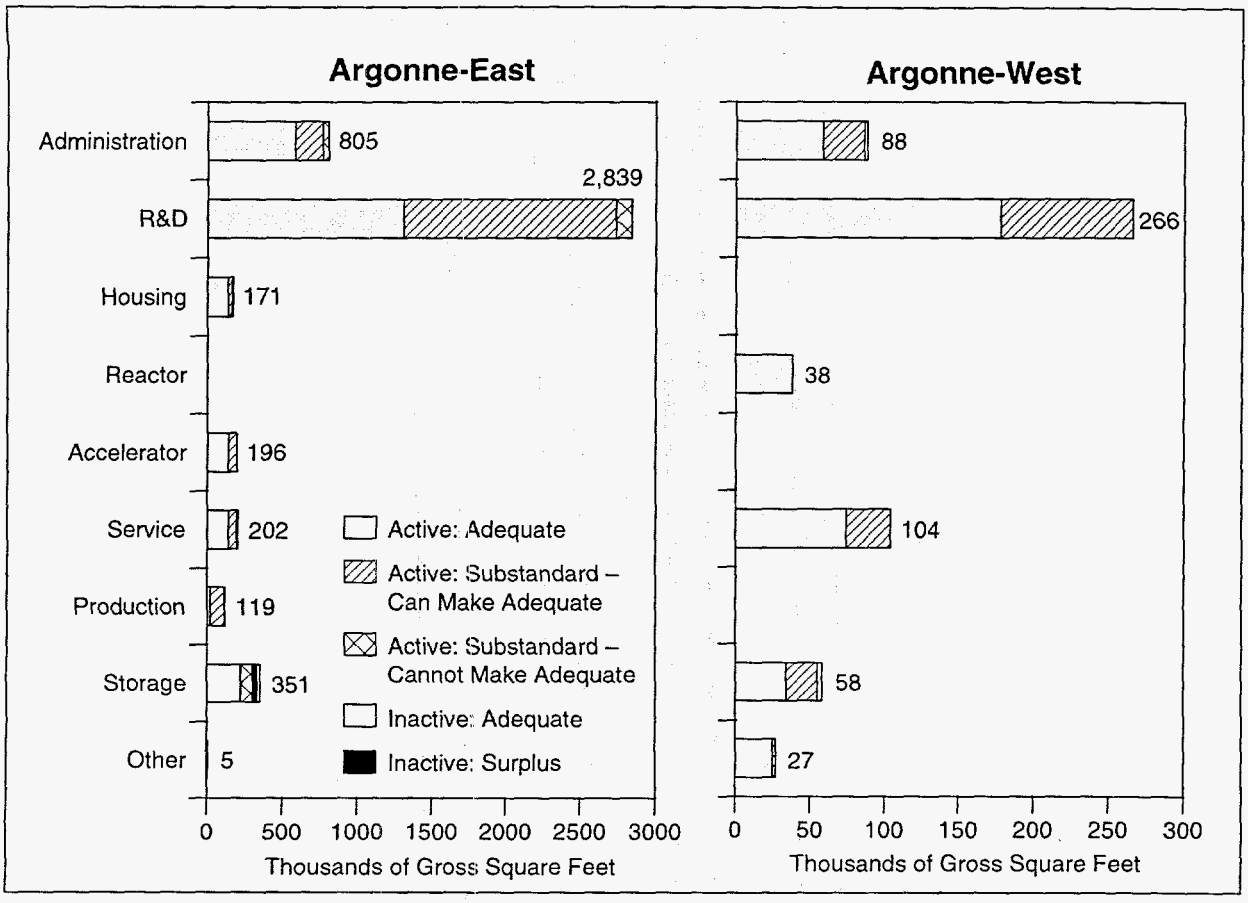
Programs for the DOE Office of Energy Research account for over half of the space usage at Argonne-East. Figure S2.1 summarizes the distribution of space at Argonne-East (and Argonne-West) by *functional unit* (administrative, housing, R&D, and so on) and by condition of space, as a percentage of gross square footage.

Altogether, Argonne-East houses roughly 6,100 persons, including employees of DOE and contractors, visiting users of research facilities, and other guests. The Argonne-East site includes 112 buildings having 4.7 million total square feet of floor space. Nearly two-thirds of the facilities are more than 30 years old. The Laboratory is also leasing 94,000 square feet of office space in a commercial park near the Argonne-East site to alleviate a space shortage. (See Table S2.1, which includes small additional amounts of space leased off-site.) Figure S2.2 summarizes the ages of Argonne-East (and Argonne-West) facilities. The replacement value of existing facilities at Argonne-East is estimated to be $1.62 billion. (See Table S2.2.)

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 continue the planned removal of obsolete and deteriorated facilities and to satisfy growing programs.

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 programmatic mission of the Argonne-West facilities changed significantly. 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.



	Space at Argonne-East					Space at Argonne-West		
	Active			Inactive		Active		
		Substandard					Substandard	
	Adequate	Can Make Adequate	Cannot Make Adequate	Adequate	Surplus	Adequate	Can Make Adequate	Cannot Make Adequate
Administration	582	184	39	0	0	58	28	2
R&D	1,309	1,429	102	0	0	178	88	0
Housing	137	29	4	0	0	0	0	0
Reactor [a]	0	0	0	0	0	38	0	0
Accelerator	140	57	0	0	0	0	0	0
Service	139	58	5	0	0	74	30	0
Production	21	93	5	0	0	0	0	0
Storage	222	2	79	27	22	34	21	3
Other	4	0	1	0	0	25	2	0
TOTAL [b]	2,553	1,852	235	27	22	407	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 S2.1 Distribution of space at Argonne-East and Argonne-West in 1997 by function and condition.

Table S2.1 Argonne-East Space Distribution

Location	Area (thousands of square feet)
Main Site	4,692
Leased Off-Site	126
Total	4,818

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 has now been shut down and 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 is being addressed at the Fuel Conditioning Facility (FCF), where sodium is being 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.

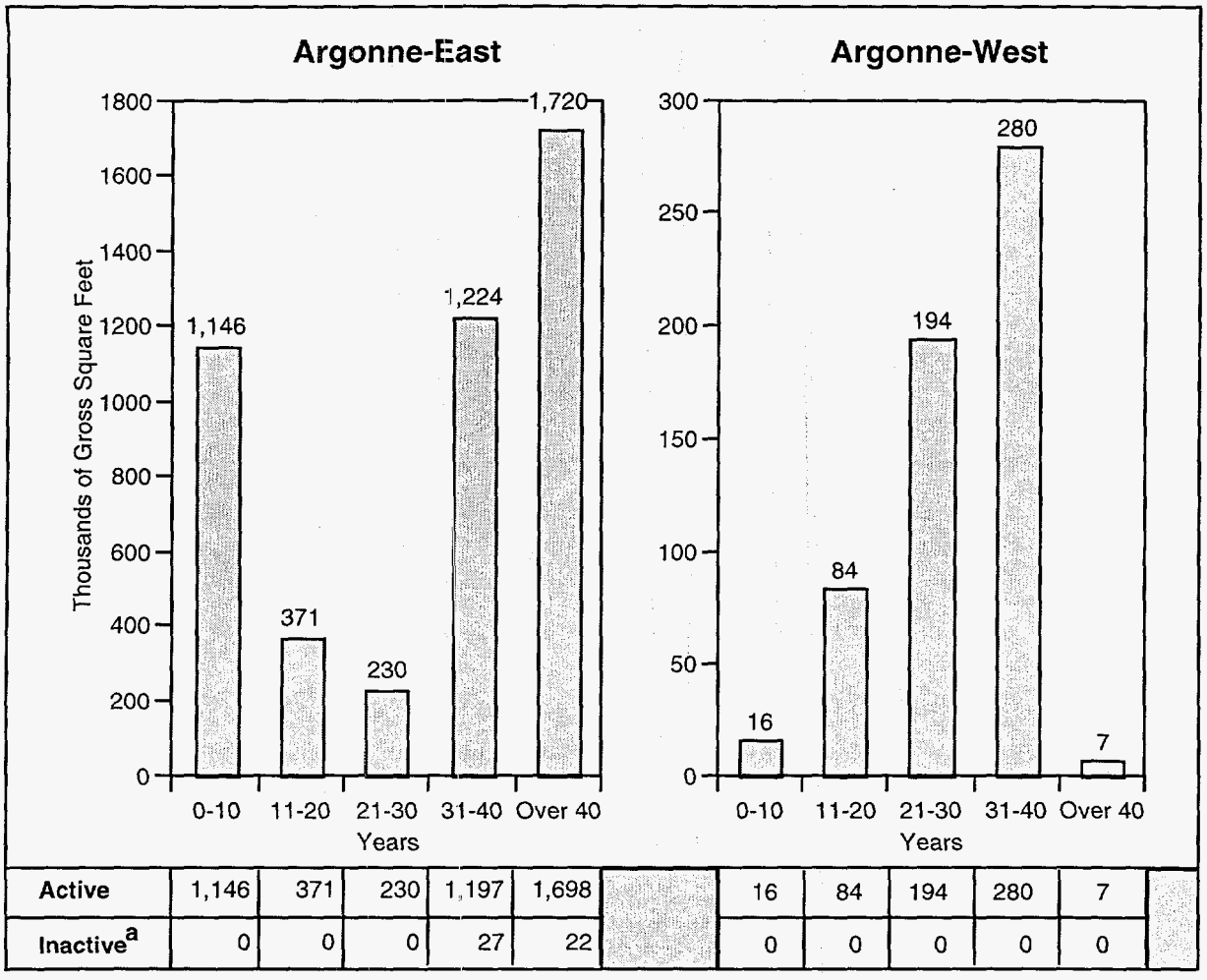
The Sodium Processing Facility treats sodium from the EBR-II and other sources, converting elemental sodium first to sodium hydroxide and then to sodium carbonate for ultimate disposal. Technology from the facility could be adapted to sodium processing for the Fast Flux Test Facility.

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, has completed 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. Equipment for materials testing and characterization is being installed in the glove boxes to support treatment of spent fuel.

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-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 S2.2 summarizes the ages of Argonne-West facilities. Replacement value of existing facilities at Argonne-West is estimated to be $352 million. (See Table S2.2.)



	Argonne-East					Argonne-West					
Active	1,146	371	230	1,197	1,698	16	84	194	280	7	
Inactive[a]	0	0	0	27	22	0	0	0	0	0	

[a]Inactive space is too small to be displayed graphically. Entries were rounded independently.

Figure S2.2 Age of Laboratory buildings at Argonne-East and Argonne-West in 1997.

Table S2.2 Replacement Value of Argonne Facilities (millions of FY 1996 dollars)

Facilities Types	Argonne-East	Argonne-West
Buildings	957	170
Utilities	110	23
All Others	555	159
Total	1,622	352

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 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 97% utilized. Figures S2.1 and S2.2 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 still require upgrades for compliance with standards and increased reliability. Major rehabilitation of the central steam plant, funded in FY 1995, is scheduled to be completed in FY 1999. Argonne's stated goal for future waste discharges is full compliance with applicable standards and regulations. The Laboratory has also completed the purchase of municipal water from an adjacent community as an alternative to continued reliance solely on obsolescing wells on-site. Use of municipal water contributes 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 S2.1 and S2.2 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 to accommodate changing missions and directives.

1. Argonne-East

On the basis of current programmatic planning, the major challenges at Argonne-East over the next 10-15 years will include improving the cost-effectiveness of facilities support for the Laboratory's changing programs in basic research and industrial technology. Long-range development plans for Argonne-East provide for the Laboratory's initiatives described in Chapter IV, 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 had also been using 64 office trailers on the Illinois site (33,000 square feet of which were leased). Space recently vacated by APS activities has been used to reduce the number of trailers and to relieve dependence on unreliable, substandard "temporary" buildings. In all, 42,000 square feet of substandard space were demolished, and an additional 43,000 square feet of trailers (36 units) were removed.

In FY 1996, the APS project achieved full beneficial occupancy of the entire complex. The state of Illinois provided $18.9 million for the design and construction of the Argonne Guest House, a 240-bed user residence facility on the APS site, within walking distance of the experiment hall. Construction of the Argonne Guest House was also completed in 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. 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. Long-range planning calls for consolidation of site support groups 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.

Environmental activities command the highest priority at Argonne. 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. The Laboratory has 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 S2.D.

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. Strategies being considered to further reduce energy consumption and its associated costs include energy savings performance contracting. The Laboratory is 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. Projects include renovation of many public areas, improved landscaping and parking areas, and general enhancements of the site's appearance to reflect its status as a world-class research facility. Argonne-East is presently expanding and remodeling its Visitor Reception Center to house the Argonne Science and Technology Information Center, which will provide for the general public interactive displays and exhibits describing the Laboratory's programs, outreach activities, and accomplishments.

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. The first is termination of the Integral Fast Reactor program and associated activities, including shutting down the EBR-II. The second major element addresses 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. 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 scrap and tanks; (4) upgrading the radioactive scrap and 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 expended to improve fire protection for major 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 also be improved. 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 and to facilitate a transition of environment, safety, and health (ES&H) regulation to the Occupational Safety and Health Administration. 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. Approximately 5% of space at the site 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, in collaboration with the DOE Chicago Operations Office, has developed a program for timely D&D of facilities no longer in use at Argonne-East, ensuring appropriate removal or containment of potential environmental hazards and allowing reuse of facilities where warranted. The program is funded by DOE-Environmental Management (DOE-EM).

Three major D&D projects were recently completed. After completion of work at the Experimental Boiling Water Reactor in Building 331, the building is being converted to a transuranic storage facility, resulting in substantial savings relative to new construction. More than 60 contaminated surplus glove boxes in Building 212 were decontaminated and downsized. Appropriate waste was packaged and sent to Hanford; remaining transuranic waste will reside in the new storage facility. Offices and laboratories in the area containing the glove boxes are now being used by other Argonne programs. Five of the hot cells in the M-Wing of Building 200 were decontaminated sufficiently to reduce radon releases, previously the largest source of off-site exposure from Argonne-East, by more than 95%. The cells are now available for future programs. The D&D of the Fast Neutron Generator (Building 314) was completed, and the area is being used for general support services. The D&D of the CP-5 Reactor is continuing and will be completed in 1999. The D&D program at CP-5 has been combined with the CP-5 Large Scale Demonstration Program. The combined program, under the direction of the Strategic Alliance for Environmental Restoration, is demonstrating and evaluating new D&D technologies. The Alliance includes Argonne, Commonwealth Edison, Duke Engineering and Services, Florida International University, ICF-Kaiser, and 3M. The D&D of the JANUS

reactor will be completed in 1997. 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, surplus retention tanks (Building 310), and the Waste Ion Exchange Facility (Building 579).

More than half of the D&D work identified in the DOE-EM *Baseline* for Argonne-East has been completed. With adequate funding, the remaining D&D work can 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 substandard buildings and removal of temporary trailers resulted in a net loss of 270,000 gross square feet. Argonne's plans call for continued removal and clearing of the old east and 800 areas of the site. Argonne-East has 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 S2.3 (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 Laboratory initiatives are discussed in Chapter IV.

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 portions of the on-site infrastructure and many severely deteriorated facilities.

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 reliability of service and continued environmental safety; and to provide suitable space for support activities.

A small number of substandard structures remain in use. The majority of the most seriously deteriorated facilities, in the 800 area, were demolished in FY 1996 as part of the ongoing site consolidation program. Removal of old supply facilities in the east area will be complete when the old structures are replaced by a new central supply facility being proposed for FY 1999 funding. Additional future MEL-FS funding will also be needed to replace modular buildings and other remaining substandard structures with more efficient facilities.

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, will ensure compliance with existing and new environmental regulations and permits, and will permit a rapid transition in regulation (from DOE to the Occupational Safety and Health Administration) in the near future.

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 are affected by the age and condition of the plant and by continuing concern for the protection of employees, the public, and the environment. Throughout the last decade, GPP funding was well below requested levels. As a consequence, many needs were deferred, and a backlog was created. Adequate GPP funding will prevent premature deterioration or failure of facilities and systems resulting from deferred repair and will also ensure compliance with ES&H regulations and permits.

F. 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 required maintenance (preventive, predictive, and corrective) 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 ensured 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 aged equipment. The average age of equipment now in use in critical areas (such as plant facilities and services, ES&H, 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 S2.4.) 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 S2.4 Projected General Purpose Equipment Funding for Argonne-East ($ in millions BA)

FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03
2.0	1.9	2.2	3.3	3.5	3.7	3.9	4.2

Table S2.3 Major Construction Projects ($ in millions BA)

	TEC	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Funded Projects									
39-AF-95									
Office of Nuclear Energy, Science and Technology									
Nuclear Energy Research and Development									
General Plant Projects, ANL-West[a]	5.0	-	1.5	-	-	-	-	-	-
Modifications to Reactors, ANL-West (95-E-207)	3.2	1.7	-	-	-	-	-	-	-
Modifications to Reactors, ANL-West[a]	2.7	-	2.7	-	-	-	-	-	-
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)	4.3	0.1	1.1	-	-	-	-	-	-
Hazardous, Radioactive, and Mixed Waste Storage Facilities, ANL-East (91-E-602)	6.6	-2.1	-	-	-	-	-	-	-
General Plant Projects, ANL-West[a]	1.8	0.4	0.3	-	-	-	-	-	-
General Plant Projects, ANL-East[a]	1.5	1.2	-	-	-	-	-	-	-
KB-02									
Office of Energy Research									
Nuclear Physics									
Accelerator Improvements, ANL-East[a]	0.8	0.3	0.5	-	-	-	-	-	-
39-KC-02									
Office of Energy Research									
Basic Energy Sciences									
Materials Sciences									
Advanced Photon Source, ANL-East (89-R-402)	467.2	3.2	-	-	-	-	-	-	-
Advanced Photon Source, Accelerator Improvements, ANL-East[a]	3.0	-	3.0	-	-	-	-	-	-

Table S2.3 Major Construction Projects (Cont.)

	TEC	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Funded Projects (Cont.)									
KC-03									
Office of Energy Research									
Basic Energy Sciences									
Chemical Sciences									
General Plant Projects, ANL-East[a]	10.5	5.7	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)	5.0	0.2	-	-	-	-	-	-	-
Central Heating Plant Rehabilitation - Phase I, ANL-East (95-E-301)	9.9	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	2.4	0.2	-	-	-	-	-	-
Fire Safety Improvements - Phase III, ANL-East (95-E-307)	3.0	1.1	1.0	0.7	-	-	-	-	-
Building Electrical Service Upgrade - Phase I, ANL-East (96-E-330)	7.9	1.2	1.1	5.5	-	-	-	-	-
39-KP-00									
Office of Energy Research									
Biological and Environmental Research									
Structural Biology Center, ANL-East (94-E-338)	14.9	4.3	-	-	-	-	-	-	-
TOTAL FUNDED PROJECTS	561.2	23.5	18.7	9.6	0.0	0.0	0.0	0.0	0.0

Table S2.3 Major Construction Projects (Cont.)

	TEC	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Budgeted Projects									
AF-95									
Office of Nuclear Energy, Science and Technology									
Nuclear Energy Research and Development									
General Plant Projects, ANL-West[a]	1.3	-	-	1.3	-	-	-	-	-
Modification to Reactors, ANL-West[a]	1.5	-	-	1.5	-	-	-	-	-
KB-02									
Office of Energy Research									
Nuclear Physics									
Accelerator Improvements, ANL-East[a]	0.4	-	-	0.4	-	-	-	-	-
39-KC-02									
Office of Energy Research									
Basic Energy Sciences									
Materials Sciences									
Advanced Photon Source, Accelerator Improvements, ANL-East[a]	3.1	-	-	3.1	-	-	-	-	-
KC-03									
Office of Energy Research									
Basic Energy Sciences									
Chemical Sciences									
General Plant Projects, ANL-East[a]	7.4	-	-	7.4	-	-	-	-	-
39-KG-01									
Office of Energy Research									
Multiprogram Energy Laboratories — General Purpose Facilities									
Electrical System Upgrade - Phase III, ANL-East (98-CH-059)	7.6	-	-	7.6	-	-	-	-	-
TOTAL BUDGETED PROJECTS	21.3	0.0	0.0	21.3	0.0	0.0	0.0	0.0	0.0
TOTAL FUNDED AND BUDGETED PROJECTS	582.5	23.5	18.7	30.9	0.0	0.0	0.0	0.0	0.0
Proposed Projects									
39-AF-95									
Office of Nuclear Energy, Science and Technology									
Nuclear Energy Research and Development									
General Plant Projects, ANL-West[a]	4.1	-	-	-	1.3	1.3	0.5	0.5	0.5
Waste Shipping Cask, ANL-West	4.6	-	-	-	-	4.6	-	-	-
Infrastructure Improvement, ANL-West	4.5	-	-	-	-	4.5	-	-	-
KB-02									
Office of Energy Research									
Nuclear Physics									
Accelerator Improvements, ANL-East[a]	4.4	-	-	-	0.8	0.9	0.9	0.9	0.9

Table S2.3 Major Construction Projects (Cont.)

	TEC	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Proposed Projects (Cont.)									
39-KC-02									
Office of Energy Research									
Basic Energy Sciences									
Materials Sciences									
Advanced Photon Source, Accelerator Improvements, ANL-East	25.5	-	-	-	5.1	5.1	5.1	5.1	5.1
39-KC-03									
Office of Energy Research									
Basic Energy Sciences									
Chemical Sciences									
General Plant Projects, ANL-East[a]	41.6	-	-	-	7.8	8.0	8.3	8.6	8.9
Accelerator Improvements, ANL-East (99-CH-070)	3.4	-	-	-	3.0	0.4	-	-	-
39-KG-01									
Office of Energy Research									
Multiprogram Energy Laboratories —									
General Purpose Facilities, ANL-East									
Building Replacement									
Central Supply Facility (99-CH-005)	6.4	-	-	-	6.4	-	-	-	-
Multiprogram Laboratory-Office Building	13.0	-	-	-	-	13.0	-	-	-
Building Rehabilitation and Upgrade									
Laboratory Space Upgrade - Phase I	5.1	-	-	-	-	5.1	-	-	-
Building Electrical Service Upgrade - Phase II	5.1	-	-	-	-	5.1	-	-	-
Building Mechanical and Control Systems Upgrade - Phase II	5.4	-	-	-	-	-	5.4	-	-
Laboratory Space Upgrade - Phase II	5.4	-	-	-	-	-	5.4	-	-
Building Electrical Service Upgrade - Phase III	5.6	-	-	-	-	-	-	5.6	-
Building Mechanical and Control Systems Upgrade - Phase III	7.6	-	-	-	-	-		7.6	-
Laboratory Space Upgrade - Phase III	5.8	-	-	-	-	-	-	-	5.8
Building Electrical Service Upgrade - Phase IV	5.8	-	-	-	-	-	-	-	5.8
Rehabilitation and Upgrade of Utility Distribution Systems									
Steam System Upgrade - Phase I	6.5	-	-	-	-	6.5	-	-	-
Roads/Parking/Walks/Street Lighting Upgrade	9.7	-	-	-	-	-	9.7	-	-
Central Heating Plant Upgrade - Phase II	10.9	-	-	-	-	-	10.9	-	-
Electrical System Upgrade - Phase IV	7.8	-	-	-	-	-	-	-	7.8
39-KG-02									
Office of Energy Research									
Multiprogram Energy Laboratories —									
Environment, Safety, and Health Support, ANL-East	6.9	-	-	-	6.9	-	-	-	-
Mechanical and Control Systems Upgrade - Phase I (99-CH-056)									
Fire Safety Improvements - Phase IV (99-CH-058)	3.6	-	-	-	3.6	-	-	-	-
Fire Safety Improvements - Phase V	3.8	-	-	-	-	-	3.8	-	-
Environmental Compliance Infrastructure Support	4.5	-	-	-	-	-	-	4.5	-
Fire Safety Improvements - Phase VI	5.7	-	-	-	-	-	-	-	5.7

[a]Funded from operating funds.

Supplement 3: Other Charts and Tables

This supplement contains charts and tables characterizing Argonne's activities in the following areas:

- Technology transfer
- Science and math education
- User facilities
- Human resources
- Environment, safety, and health

A. Technology Transfer

Table S3.1 summarizes Argonne's actual and planned funding and staffing for the Laboratory's continuing aggressive pursuit of technology transfer. Table S3.2 describes licensing income and use.

B. Science and Math Education

Table S3.3 characterizes Argonne's existing educational programs. The total number of appointments and the number of minorities and women are shown for FY 1995 and FY 1996.

C. User Facilities

Table S3.4 describes experimenters at the Argonne user facilities that have been officially designated as such by DOE.

In highly abbreviated terms, these facilities provide the following important scientific capabilities:

- *Advanced Photon Source (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.

D. Human Resources

Argonne's employees are highly educated. Table S3.5 summarizes the academic degrees held by permanent staff at the end of FY 1996. Table S3.6 describes the distribution of Argonne employees among various racial and ethnic categories.

E. Environment, Safety, and Health

Argonne's *ES&H Management Plan* identifies the programs and resources needed for continued success in the Laboratory's safety and health programs. Table S3.7 summarizes funding needs identified in Argonne's current plan.

The DOE Office of Environmental Management supports environmental restoration and waste management programs at Argonne. Table S3.8 summarizes the planned funding for these programs.

Table S3.1 Technology Transfer Funding and Effort[a]

	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Funding ($1,000)							
ORTA/Industrial Technology Development Center[b]	2,156	2,200	2,300	2,400	2,500	2,600	2,700
ER-LTR[c]	2,400	2,500	3,000	3,000	3,000	3,000	3,000
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
Other cost-shared contracts	1,500	1,500	1,500	2,000	2,000	2,000	2,000
Total Federal Cooperative Research Funding	29,056	31,200	34,800	40,400	45,500	50,600	55,700
Total Industry Funding	40,000	50,000	50,000	60,000	60,000	65,000	65,000
Staffing (FTE)[e]							
ORTA/Industrial Technology Development Center Activity	7	6	6	6	6	6	6
Patent/Licensing Activity	5	5	5	5	5	5	5
CRADA/HTSCA Activity	7	6	6	6	6	6	6
Total Staffing	19	17	17	17	17	17	17

[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 Supplement 1 and Supplement 4.

[e]Staffing does not include researchers involved in CRADA/HTSCA activity.

Table S3.2 Licensing Income and Use

	FY96	FY97	FY98	FY99	FY00
Licenses[a]					
Number of New Licenses					
ARCH	0	2	2	2	2
Argonne	11	12	12	12	12
License Income[b] ($1,000)					
ARCH	1,915	150	150	150	150
Argonne	36	200	200	200	200
Total	1,951	350	350	350	350
Use of Income ($1,000)					
ARCH Administration[c]	1,436	112	112	112	112
ORTA Administration	0	0	0	0	0
Laboratory R&D[d]	27	150	150	150	150
Awards and Inventor Payments[e]	488	88	88	88	88
Total	1,951	350	350	350	350

[a]Includes licensing, options to license, and assignments to industry.

[b]Includes $1,844,000 in FY 1996 from the public sale of stock used by ARCH as start-up monies.

[c]Equals 75% of ARCH royalties.

[d]Equals 75% of Argonne royalties.

[e]Equals 25% of total royalties.

Table S3.3 Participation in Science and Math Educational Programs

Programs	FY 1995 Total	FY 1995 Under-represented Minorities[a]	FY 1995 Women	FY 1996 Total	FY 1996 Under-represented Minorities[a]	FY 1996 Women	FY 1997 Projected Total
Outreach Activities							
Students							
Instructional Vehicle	16,595	8,752	8,466	15,410	7,143	8,116	15,000
Student Conference	374	144	374	388	-	388	390
Teachers							
Internet Training	427	55	243	495	62	340	622
Argonne Community of Teachers	80	8	36	51	11	30	60
Microscale Chemistry	76	4	46	-	-	-	-
Undergraduate Programs							
Summer Research Participation	215	38	62	215	31	71	220
Science Engineering Research Semester	123	10	37	126	11	39	110
Instructional Laboratory	265	30	143	228	50	122	-
Undergraduate Research Symposium	157	-	-	195	-	-	200
Graduate Programs							
Thesis Graduate Students	155	7	46	135	6	42	90
Postdoctoral Fellows	151	4	22	166	4	29	150
Faculty Programs							
Faculty Research Participation	48	7	9	50	17	11	40
Sabbatical Leave	13	-	1	6	-	1	5
Faculty Visits	30	1	4	32	4	4	30
Diversity Initiative							
Student Interdisciplinary Research Training	28	28	-	26	26	14	30

[a]Underrepresented minorities include African-Americans, Hispanics, and Native Americans.

Table S3.4 Experimenters at Designated Argonne User Facilities — FY 1996

	Laboratory[a]		University		Industry		Other[b]		Totals	
	No.	*% Use*	No.	*% Use*	No.	*% Use*	No.	*% Use*	No.	*% Use*
APS[c]	118	*35*	152	*45*	67	*20*	1	*<1*	338	*100*
IPNS	76	*38*	85	*42*	7	*4*	33	*16*	201	*100*
ATLAS	52	*30*	93	*54*	-	-	27	*16*	172	*100*
High Voltage Electron Microscope-Tandem Accelerator Facility	33	*40*	42	*52*	2	*2*	5	*6*	82	*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.

[c]Numbers of experimenters indicated for APS start-up operations in FY96 include qualified users engaged in beamline installation and commissioning, as well as those engaged in initial experimentation. Scheduled user beam time in FY96 amounted to 1,576 hours or 18% of the total year.

Table S3.5 Academic Degrees of Argonne Staff[a]

Category	PhD	MS/MA	BS/BA	Other[b]	Total
Scientists and Engineers					
Supervisors	232	97	61	26	416
Nonsupervisors	570	320	313	138	1,341
Support Staff					
Officials and Managers	15	50	43	56	164
Administrators (Nonsupervisory)	17	64	109	93	283
Technicians	0	2	66	570	638
All Others	0	1	66	1,136	1,203
Laboratory Total	834	534	658	2,019	4,045

[a]Number of full- and part-time employees at the end of FY96. Scientists are included in the management and administrative category if that is their primary duty.

[b]Associate level degree or less.

Table S3.6 Population of Laboratory Employees[a]

September 30, 1996

Occupational Category	Total				Minority Total				White				Black				Hispanic				Native American				Asian			
	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.	%
Scientists and Engineers																												
Officials and Managers	377	90.6	39	9.4	30	7.2	4	1.0	347	83.4	35	8.4	3	0.7	2	0.5	3	0.7	0	0.0	1	0.2	0	0.0	23	5.5	2	0.5
Nonsupervisors	1,174	87.5	167	12.5	157	11.7	26	1.9	1,017	75.8	141	10.5	10	0.7	2	0.1	16	1.2	3	0.2	2	0.1	0	0.0	129	9.6	21	1.6
Support Staff																												
Officials and Managers	112	68.3	52	31.7	6	3.7	4	2.4	106	64.6	48	29.3	3	1.8	2	1.2	1	0.6	1	0.6	2	1.2	0	0.0	0	0.0	1	0.6
Administrators	126	44.5	157	55.5	8	2.8	23	8.1	118	41.7	134	47.3	4	1.4	7	2.5	2	0.7	5	1.8	0	0.0	1	0.4	2	0.7	10	3.5
Technicians	570	89.3	68	10.7	51	8.0	8	1.3	519	81.3	60	9.4	25	3.9	3	0.5	13	2.0	0	0.0	3	0.5	1	0.2	10	1.6	4	0.6
All Others	552	45.9	651	54.1	105	8.7	123	10.2	447	37.2	528	43.9	76	6.3	77	6.4	20	1.7	30	2.5	4	0.3	5	0.4	5	0.4	11	0.9
Totals	2,911	72.0	1,134	28.0	357	8.8	188	4.6	2,554	63.1	946	23.4	121	3.0	93	2.3	55	1.4	39	1.0	12	0.3	7	0.2	169	4.2	49	1.2

September 30, 1991

Occupational Category	Total				Minority Total				White				Black				Hispanic				Native American				Asian			
	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.	%
Scientists and Engineers																												
Officials and Managers	339	97.1	10	2.9	23	6.6	1	0.3	316	90.5	9	2.6	2	0.6	0	0.0	2	0.6	0	0.0	2	0.6	0	0.0	17	4.9	1	0.3
Nonsupervisors	1,272	87.7	179	12.3	167	11.5	20	1.4	1,105	76.2	159	11.0	11	0.8	4	0.3	9	0.6	1	0.1	2	0.1	0	0.0	145	10.0	15	1.0
Support Staff																												
Officials and Managers	157	78.5	43	21.5	10	5.0	3	1.5	147	73.5	40	20.0	2	1.0	2	1.0	4	2.0	1	0.5	3	1.5	0	0.0	1	0.5	0	0.0
Administrator	128	51.8	119	48.2	12	4.9	16	6.5	116	47.0	103	41.7	7	2.8	6	2.4	3	1.2	3	1.2	1	0.4	2	0.8	1	0.4	5	2.0
Technicians	521	91.7	47	8.3	38	6.7	7	1.2	483	85.0	40	7.0	20	3.5	3	0.5	7	1.2	0	0.0	5	0.9	1	0.2	6	1.1	3	0.5
All Others	546	44.7	676	55.3	113	9.2	122	10.0	433	35.4	554	45.3	85	7.0	77	6.3	21	1.7	28	2.3	3	0.2	7	0.6	4	0.3	10	0.8
Totals	2,963	73.4	1,074	26.6	363	9.0	169	4.2	2,600	64.4	905	22.4	127	3.1	92	2.3	46	1.1	33	0.8	16	0.4	10	0.2	174	4.3	34	0.8

[a]Includes both the Illinois and Idaho sites. Percentages are calculated separately within each occupational category.

Table S3.7 Safety and Health Plan Funding for Argonne-East and Argonne-West[a]

($ in millions BA)

	FY97	FY98	FY99	FY00	FY01	FY02	FY03
Argonne-East							
Operating	20.0	23.2	21.8	22.6	23.7	24.1	24.6
Capital Equipment	0.5	0.6	0.9	0.7	0.8	0.8	0.8
General Plant Projects	0.5	1.8	3.8	2.0	2.0	2.1	2.2
Line Items	2.4	6.0	0.9	5.6	9.1	6.5	5.0
Total	23.4	31.6	27.4	30.9	35.6	33.5	32.6
Argonne-West							
Operating	11.5	11.4	11.9	12.6	12.6	13.2	13.9
Capital Equipment	-	0.3	-	-	-	-	-
General Plant Projects	-	0.2	-	0.6	0.4	0.2	-
Line Items	-	-	-	-	-	-	-
Total	11.5	11.9	11.9	13.2	13.0	13.4	13.9

[a]Based on the FY99 DOE *Environment, Safety and Health Management Plans*. Includes environmental activities supported with indirect funds and with direct programmatic funding, primarily from DOE-Energy Research. Excludes activities funded by DOE-Environmental Management, including waste management, environmental restoration, and decontamination and decommissioning (see Table S3.8).

Table S3.8 Environmental Restoration and Waste Management Programs: Funding Requirements for Argonne-East and Argonne-West[a] ($ in millions BA; personnel in FTE)

	FY97	FY98	FY99	FY00	FY01	FY02	FY03
ARGONNE-EAST							
Environmental Restoration							
Operating	9.4	7.8	21.1	12.7	8.0	0.0	0.0
Capital Equipment	-	-	-	-	-	-	-
General Plant Projects	-	-	-	-	-	-	-
Line Items	-	-	-	-	-	-	-
Total	9.4	7.8	21.1	12.7	8.0	0.0	0.0
Direct Personnel	24.1	22.0	38.0	29.0	16.8	0.0	0.0
Waste Management							
Operating	8.1	7.4	7.9	7.9	7.9	7.9	7.4
Capital Equipment	0.2	0.2	0.2	0.2	0.2	0.2	0.2
General Plant Projects	-	-	-	-	-	-	
Line Items	1.1	-	-	-	-	-	
Total	9.4	7.6	8.1	8.1	8.1	8.1	7.6
Direct Personnel	52.2	47.2	47.2	47.2	47.2	47.2	44.0
ARGONNE-WEST							
Environmental Restoration							
Operating	1.8	2.4	3.7	0.5	0.2	0.1	0.1
Capital Equipment	-	-	-	-	-	-	-
General Plant Projects	-	-	-	-	-	-	-
Line Items	-	-	-	-	-	-	-
Total	1.8	2.4	3.7	0.5	0.2	0.1	0.1
Direct Personnel	5.0	5.0	5.0	3.0	1.0	0.0	0.0
Waste Management							
Operating	5.2	3.2	3.3	3.2	3.2	3.2	3.2
Capital Equipment	-	-	-	-	-	-	-
General Plant Projects	0.3	0.3	0.2	0.3	0.3	0.3	0.3
Line Items	-	-	-	-	-	-	-
Total	5.5	3.5	3.5	3.5	3.5	3.5	3.5
Direct Personnel	11.0	11.0	11.0	11.0	11.0	11.0	11.0

[a]This table reflects DOE guidance for Argonne's FY99 Project Baseline Summary — Funding for Remedial Actions, Program Management, and Waste Operations. (Compare with the resource table for all of DOE-Environmental Management, which combines Argonne-East and Argonne-West and includes other funding as well.)

Supplement 4: Resource Projections

The resource projections in this supplement 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 1997 generally are not included in these resource projections. Funds received in FY 1996 and FY 1997 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 S4.1 and S4.19, which also specify funding for proposed construction projects.

The figures for FY 1996 and FY 1997 represent historical dollar values. Projections to FY 1998 incorporate annual cost escalation of 5.0% for effort and 3.1% for materials and services. Escalation rates for FY 1999 are, respectively, 5.0% and 3.1%. Operating costs beyond FY 1999 are expressed in FY 1999 dollars.

The year-to-year escalation rates for construction costs, from FY 1998 to FY 2003, are provided by DOE.

The resource projections are presented in 21 tables:

- Tables S4.1 and S4.2 summarize Laboratory total funding and personnel levels, respectively.
- Tables S4.3-S4.18 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 S4.3-S4.16 describe work funded by DOE, Table S4.17 lists work funded by DOE contractors, and Table S4.18 pertains to work funded by all other organizations.
- Table S4.19 summarizes the information in Tables S4.3-S4.18, giving total Laboratory funding for each DOE secretarial office.
- Table S4.20 and Table S4.21 summarize subcontracting and procurement at the Laboratory, with the latter table detailing procurements from small and disadvantaged businesses.

Table S4.1 Laboratory Funding Summary ($ in millions BA)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
DOE Effort	395.3	376.8	402.7	427.3	428.3	422.9	422.7	421.9
Work for Sponsors Other than DOE	64.3	75.0	67.2	65.7	65.4	65.4	65.4	65.4
Total Operating	459.6	451.8	469.9	493.0	493.7	488.3	488.1	487.3
Capital Equipment	22.6	14.0	18.7	26.2	26.8	26.2	25.7	25.7
Construction	8.7	7.3	5.0	0.0	0.0	0.0	0.0	0.0
Inventory	-1.3	0.0	0.2	0.5	0.5	0.5	0.5	0.5
General Purpose Equipment[a]	2.0	1.9	2.2	3.3	3.5	3.7	3.9	4.2
General Plant Projects[a]	7.3	6.6	8.7	9.1	9.3	8.8	9.1	9.4
Multiprogram Energy Laboratories — Facilities Support Program	7.5	4.8	17.2	0.0	0.0	0.0	0.0	0.0
Total Laboratory Funding	506.4	486.4	521.9	532.1	533.8	527.5	527.3	527.1
Proposed Projects:								
Program Construction	0.0	0.0	0.0	8.9	15.5	6.0	6.0	6.0
Multiprogram Energy Laboratories — Facilities Support Program	0.0	0.0	0.0	16.9	29.7	35.2	17.7	25.1
Total Projected Funding	506.4	486.4	521.9	557.9	579.0	568.7	551.0	558.2

[a]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 S4.2 Laboratory Personnel Summary (in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Direct Personnel								
DOE Effort	2190.8	2020.3	2023.6	2024.9	1960.0	1928.3	1915.3	1900.3
Work for Sponsors Other than DOE	337.8	343.2	310.3	305.8	304.7	300.3	300.3	300.3
Total Operating	2528.6	2363.5	2333.9	2330.7	2264.7	2228.6	2215.6	2200.6
Other Direct	536.0	534.6	536.2	535.7	520.2	512.0	509.1	505.6
Total Direct Personnel[a]	3064.6	2898.1	2870.1	2866.4	2784.9	2740.6	2724.7	2706.2
Indirect Personnel	1570.6	1565.4	1569.9	1568.6	1522.9	1499.0	1490.5	1480.5
Total Personnel	4635.2	4463.5	4440.0	4435.0	4307.8	4239.6	4215.2	4186.7

[a]Direct personnel for FY96 include an estimated 400 technical service FTEs that are not included in the detailed program tables.

Table S4.3 Nuclear Energy, Science and Technology: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Nuclear Energy Research and Development (AF)								
Operating	92.6	88.4	107.2	107.0	106.0	104.4	104.2	103.4
Capital Equipment	3.0	1.0	1.0	2.5	2.5	2.5	2.5	2.5
Construction (Modifications to Reactors)	1.7	2.7	1.5	–	–	–	–	–
General Plant Projects	–	1.5	1.3	1.3	1.3	0.5	0.5	0.5
Total	97.3	93.6	111.0	110.8	109.8	107.4	107.2	106.4
Direct Personnel	453.0	458.9	526.8	513.7	501.2	487.5	474.5	459.5
Uranium Programs Activities (CD-10)								
Operating	3.2	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	3.2	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Direct Personnel	20.1	14.8	9.0	9.0	9.0	9.0	9.0	9.0
Program Direction — Nuclear Energy (KK-05)								
Operating	–	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	–	–	–	–	–	–	–	–
Total Nuclear Energy, Science and Technology								
Operating	95.8	89.9	108.7	108.5	107.5	105.9	105.7	104.9
Capital Equipment	3.0	1.0	1.0	2.5	2.5	2.5	2.5	2.5
Construction	1.7	2.7	1.5	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	1.5	1.3	1.3	1.3	0.5	0.5	0.5
Total	100.5	95.1	112.5	112.3	111.3	108.9	108.7	107.9
Direct Personnel	473.1	473.7	535.8	522.7	510.2	496.5	483.5	468.5

Table S4.4 Energy Research: Resources by Subprogram ($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Fusion Energy Sciences (AT)								
Operating	5.2	2.3	3.3	3.7	4.0	4.0	4.0	4.0
Capital Equipment	0.1	–	0.1	0.1	0.1	0.1	0.1	0.1
Construction	–	–	–	–	–	–	–	–
Total	5.3	2.3	3.4	3.8	4.1	4.1	4.1	4.1
Direct Personnel	20.7	14.0	15.1	17.1	17.2	16.9	16.9	16.9
Life Sciences (KP-11)								
Operating	8.2	7.3	7.5	7.5	7.5	7.5	7.5	7.5
Capital Equipment	0.7	0.1	1.7	0.8	0.8	0.8	0.8	0.8
Construction	4.3	–	–	–	–	–	–	–
Total	13.2	7.4	9.2	8.3	8.3	8.3	8.3	8.3
Direct Personnel	41.5	45.1	41.5	40.1	40.1	40.1	40.1	40.1
Environmental Processes (KP-12)								
Operating	3.0	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Capital Equipment	0.5	–	0.1	0.2	0.2	0.2	0.2	0.2
Construction	–	–	–	–	–	–	–	–
Total	3.5	2.9	3.0	3.1	3.1	3.1	3.1	3.1
Direct Personnel	12.2	14.9	14.3	14.0	14.0	14.0	14.0	14.0
Environmental Remediation (KP-13)								
Operating	0.2	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	–	–	–	–	–	–	–
Direct Personnel	1.1	–	–	–	–	–	–	–
Total Biological and Environmental Research (KP)								
Operating	11.4	10.2	10.4	10.4	10.4	10.4	10.4	10.4
Capital Equipment	1.2	0.1	1.8	1.0	1.0	1.0	1.0	1.0
Construction	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	16.9	10.3	12.2	11.4	11.4	11.4	11.4	11.4
Direct Personnel	54.8	60.0	55.8	54.1	54.1	54.1	54.1	54.1

Table S4.4 Energy Research: Resources by Subprogram (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Total High Energy Physics (KA)								
Operating	7.9	7.5	8.5	8.9	9.4	9.4	9.4	9.4
Capital Equipment	1.0	1.0	2.5	4.7	5.0	4.5	4.0	4.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	8.9	8.5	11.0	13.6	14.4	13.9	13.4	13.4
Direct Personnel	54.0	54.6	56.4	58.7	59.6	59.6	59.6	59.6
Medium Energy Physics (KB-01)								
Operating	3.1	3.1	3.1	3.7	3.7	3.7	3.7	3.7
Capital Equipment	1.3	0.2	0.2	0.4	0.4	0.4	0.4	0.4
Construction	–	–	–	–	–	–	–	–
Total	4.4	3.3	3.3	4.1	4.1	4.1	4.1	4.1
Direct Personnel	17.7	20.4	19.8	21.7	21.7	21.7	21.7	21.7
Heavy-Ion Physics (KB-02)								
Operating	9.9	10.0	10.6	12.2	12.2	12.2	12.2	12.2
Capital Equipment	–	1.2	1.2	1.6	1.6	1.6	1.6	1.6
Construction	0.3	0.5	0.4	–	–	–	–	–
Total	10.2	11.7	12.2	13.8	13.8	13.8	13.8	13.8
Direct Personnel	61.6	69.8	74.0	78.6	78.6	78.6	78.6	78.6
Nuclear Theory (KB-03)								
Operating	0.9	0.9	0.9	1.2	1.2	1.2	1.2	1.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.9	0.9	0.9	1.2	1.2	1.2	1.2	1.2
Direct Personnel	6.5	6.7	7.7	8.5	8.5	8.5	8.5	8.5
Low Energy Physics (KB-04)								
Operating	0.3	0.3	0.3	1.4	1.4	1.4	1.4	1.4
Capital Equipment	–	–	–	0.2	0.2	0.2	0.2	0.2
Construction	–	–	–	–	–	–	–	–
Total	0.3	0.3	0.3	1.6	1.6	1.6	1.6	1.6
Direct Personnel	1.3	1.7	6.5	7.1	7.1	7.1	7.1	7.1

Table S4.4 Energy Research: Resources by Subprogram (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Total Nuclear Physics (KB)								
Operating	14.2	14.3	14.9	18.5	18.5	18.5	18.5	18.5
Capital Equipment	1.3	1.4	1.4	2.2	2.2	2.2	2.2	2.2
Construction	0.3	0.5	0.4	0.0	0.0	0.0	0.0	0.0
Total	15.8	16.2	16.7	20.7	20.7	20.7	20.7	20.7
Direct Personnel	87.1	98.6	108.0	115.9	115.9	115.9	115.9	115.9
Materials Sciences (KC-02)								
Operating	27.8	26.8	28.8	28.9	35.0	35.0	35.0	35.0
Capital Equipment	3.9	1.7	2.6	3.9	4.2	4.2	4.2	4.2
Construction	–	–	–	–	–	–	–	–
Total	31.7	28.5	31.4	32.8	39.2	39.2	39.2	39.2
Direct Personnel	154.1	158.9	161.3	162.9	167.2	167.2	167.2	167.2
Advanced Photon Source (KC-02)								
Operating	75.8	75.9	79.0	92.0	92.0	92.0	92.0	92.0
Capital Equipment	7.3	2.6	2.6	5.5	5.5	5.5	5.5	5.5
Construction	3.2	3.0	3.1	–	–	–	–	–
Total	86.3	81.5	84.7	97.5	97.5	97.5	97.5	97.5
Direct Personnel	408.4	411.4	429.1	440.3	440.3	440.3	440.3	440.3
Total Materials Sciences (KC-02)								
Operating	103.6	102.7	107.8	120.9	127.0	127.0	127.0	127.0
Capital Equipment	11.2	4.3	5.2	9.4	9.7	9.7	9.7	9.7
Construction	3.2	3.0	3.1	0.0	0.0	0.0	0.0	0.0
Total	118.0	110.0	116.1	130.3	136.7	136.7	136.7	136.7
Direct Personnel	562.5	570.3	590.4	603.2	607.5	607.5	607.5	607.5
Chemical Sciences (KC-03)								
Operating	17.9	16.2	16.5	17.3	18.2	18.2	18.2	18.2
Capital Equipment	2.7	2.7	2.7	2.8	2.9	2.9	2.9	2.9
General Purpose Equipment	2.0	1.9	2.2	3.3	3.5	3.7	3.9	4.2
Construction	–	–	–	–	–	–	–	–
General Plant Projects	5.7	4.8	7.4	7.8	8.0	8.3	8.6	8.9
Total	28.3	25.6	28.8	31.2	32.6	33.1	33.6	34.2
Direct Personnel	90.0	87.5	89.0	93.0	98.0	98.0	98.0	98.0

Table S4.4 Energy Research: Resources by Subprogram (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Engineering and Geosciences (KC-04)								
Operating	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Capital Equipment	0.6	0.6	0.2	0.2	0.2	0.2	0.2	0.2
Construction	–	–	–	–	–	–	–	–
Total	1.2	1.2	0.8	0.8	0.8	0.8	0.8	0.8
Direct Personnel	3.0	4.0	5.7	5.7	5.0	4.0	4.0	4.0
Total Basic Energy Sciences (KC-02, KC-03, KC-04)								
Operating	122.1	119.5	124.9	138.8	145.8	145.8	145.8	145.8
Capital Equipment	14.5	7.6	8.1	12.4	12.8	12.8	12.8	12.8
General Purpose Equipment	2.0	1.9	2.3	3.3	3.5	3.7	3.9	4.2
Construction	3.2	3.0	3.1	0.0	0.0	0.0	0.0	0.0
General Plant Projects	5.7	4.8	7.4	7.8	8.0	8.3	8.6	8.9
Total	147.5	136.8	145.7	162.3	170.1	170.6	171.1	171.7
Direct Personnel	655.5	661.8	685.1	701.9	710.5	709.5	709.5	709.5
Program Technology Assessment (KD-01)								
Operating	0.3	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.3	–	–	–	–	–	–	–
Direct Personnel	2.8	–	–	–	–	–	–	–
Total Energy Research Analysis (KD)								
Operating	0.3	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	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Infrastructure Support (KG-04)								
Operating	1.2	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.2	–	–	–	–	–	–	–
Direct Personnel	3.5	0.2	–	–	–	–	–	–

Table S4.4 Energy Research: Resources by Subprogram (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Total Multiprogram Energy Laboratories — Facility Support (KG)								
Operating	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	3.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Mathematical, Information, and Computational Sciences (KJ-01)								
Operating	11.5	12.2	13.2	19.5	19.5	19.5	19.5	19.5
Capital Equipment	0.2	0.6	0.7	0.7	0.7	0.7	0.7	0.7
Construction	–	–	–	–	–	–	–	–
Total	11.7	12.8	13.9	20.2	20.2	20.2	20.2	20.2
Direct Personnel	31.3	38.5	50.8	52.9	52.9	52.9	52.9	52.9
Laboratory Technology Research (KJ-02)								
Operating	3.0	2.0	3.1	6.0	6.0	6.0	6.0	6.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	3.0	2.0	3.1	6.0	6.0	6.0	6.0	6.0
Direct Personnel	4.6	19.5	20.3	36.9	36.9	36.9	36.9	36.9
Advanced Energy Projects (KJ-03)								
Operating	0.8	1.4	0.9	0.6	0.6	0.6	0.6	0.6
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.8	1.4	0.9	0.6	0.6	0.6	0.6	0.6
Direct Personnel	4.9	7.5	4.6	2.7	2.7	2.7	2.7	2.7
Total Computational and Technology Research (KJ)								
Operating	15.3	15.6	17.2	26.1	26.1	26.1	26.1	26.1
Capital Equipment	0.2	0.6	0.7	0.7	0.7	0.7	0.7	0.7
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	15.5	16.2	17.9	26.8	26.8	26.8	26.8	26.8
Direct Personnel	40.8	65.5	75.7	92.5	92.5	92.5	92.5	92.5

Table S4.4 Energy Research: Resources by Subprogram (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Total Energy Research								
Operating	177.6	169.4	179.2	206.4	214.2	214.2	214.2	214.2
Capital Equipment	18.3	10.7	14.6	21.1	21.8	21.3	20.8	20.8
General Purpose Equipment	2.0	1.9	2.2	3.3	3.5	3.7	3.9	4.2
Construction	7.8	3.5	3.5	0.0	0.0	0.0	0.0	0.0
General Plant Projects	5.7	4.8	7.4	7.8	8.0	8.3	8.6	8.9
Subtotal	211.4	190.3	206.9	238.6	247.5	247.5	247.5	248.1
Direct Personnel	919.2	954.7	996.1	1040.2	1049.8	1048.5	1048.5	1048.5
Inventory	-1.3	0.0	0.2	0.5	0.5	0.5	0.5	0.5
Multiprogram Energy Laboratories — Facilities Support Program	7.5	4.8	17.2	0.0	0.0	0.0	0.0	0.0
Total Energy Research	217.6	195.1	224.3	239.1	248.0	248.0	248.0	248.6

Table S4.5 Federal Energy Regulatory Commission ($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Federal Energy Regulatory Commission (VR)								
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	0.2	0.7	0.6	0.6	0.6	0.6	0.6	0.6

Table S4.6 Energy Efficiency and Renewable Energy: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Solar Technology Transfer (EB-28)								
Operating	0.2	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	–	–	–	–	–	–	–
Direct Personnel	0.1	0.1	–	–	–	–	–	–
Electric Energy Systems and Storage (EB-50)								
Operating	3.4	2.9	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	3.4	2.9	4.4	5.5	5.5	5.5	5.5	5.5
Direct Personnel	14.5	19.6	23.8	27.3	27.3	27.3	27.3	27.3
Total Solar and Renewable Resource Technologies (EB)								
Operating	3.6	2.9	4.0	5.0	5.0	5.0	5.0	5.0
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	3.6	2.9	4.4	5.5	5.5	5.5	5.5	5.5
Direct Personnel	14.6	19.7	23.8	27.3	27.3	27.3	27.3	27.3
Building System Design (EC-10)								
Operating	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	0.8	2.5	2.1	2.2	2.2	2.2	2.2	2.2
Building Equipment and Materials (EC-12)								
Operating	–	0.1	0.2	0.3	0.3	0.3	0.3	0.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	0.1	0.2	0.3	0.3	0.3	0.3	0.3
Direct Personnel	–	0.3	1.0	1.3	1.3	1.3	1.3	1.3

Table S4.6 Energy Efficiency and Renewable Energy: Resources by Subprogram (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Total Building Technology, State and Community Sector (EC)								
Operating	0.2	0.6	0.7	0.8	0.8	0.8	0.8	0.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.2	0.6	0.7	0.8	0.8	0.8	0.8	0.8
Direct Personnel	0.8	2.8	3.1	3.5	3.5	3.5	3.5	3.5
Industries of the Future (Specific) (ED-18)								
Operating	4.3	4.8	5.7	6.1	5.2	5.2	5.2	5.2
Capital Equipment	–	0.1	0.6	0.1	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	4.3	4.9	6.3	6.2	5.2	5.2	5.2	5.2
Direct Personnel	19.5	25.9	28.0	29.8	23.1	23.1	23.1	23.1
Industries of the Future (Crosscutting) (ED-19)								
Operating	–	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.6	1.0	1.3	1.5	1.5	1.5	1.5	1.5
Municipal Solid Wastes (ED-31)								
Operating	–	0.1	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	0.1	–	–	–	–	–	–
Direct Personnel	–	0.1	–	–	–	–	–	–
Technology Access (ED-32)								
Operating	0.1	0.1	0.3	0.2	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	0.1	0.3	0.2	0.1	0.1	0.1	0.1
Direct Personnel	0.3	1.1	1.6	1.4	0.2	0.2	0.2	0.2
Total Industry Sector (ED)								
Operating	4.4	5.1	6.2	6.5	5.5	5.5	5.5	5.5
Capital Equipment	0.0	0.1	0.6	0.1	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	4.4	5.2	6.8	6.6	5.5	5.5	5.5	5.5
Direct Personnel	20.4	28.1	30.9	32.7	24.8	24.8	24.8	24.8

Table S4.6 Energy Efficiency and Renewable Energy: Resources by Subprogram (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Alternative Fuels Utilization (EE-05)								
Operating	2.0	2.6	3.2	3.3	3.5	3.5	3.5	3.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	2.0	2.6	3.2	3.3	3.5	3.5	3.5	3.5
Direct Personnel	7.6	14.8	12.5	12.7	12.9	12.9	12.9	12.9
Electric Drive Vehicle Technologies (EE-06)								
Operating	4.2	5.1	6.3	6.9	6.9	6.9	6.9	6.9
Capital Equipment	0.4	0.4	0.9	0.5	0.5	0.5	0.5	0.5
Construction	–	–	–	–	–	–	–	–
Total	4.6	5.5	7.2	7.4	7.4	7.4	7.4	7.4
Direct Personnel	14.2	24.9	23.5	25.1	25.1	25.1	25.1	25.1
Transportation Materials Technologies (EE-07)								
Operating	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	4.6	2.2	1.2	1.5	1.5	1.5	1.5	1.5
Combustion Engine R&D (EE-08)								
Operating	0.9	0.5	1.0	1.0	1.0	1.0	1.0	1.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.9	0.5	1.0	1.0	1.0	1.0	1.0	1.0
Direct Personnel	1.8	7.9	4.7	4.5	4.4	4.4	4.4	4.4
Implementation and Program Management (EE-09)								
Operating	1.2	1.0	1.1	1.2	1.2	1.2	1.2	1.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.2	1.0	1.1	1.2	1.2	1.2	1.2	1.2
Direct Personnel	6.3	4.1	3.9	4.0	4.1	4.1	4.1	4.1
Total Transportation Sector (EE)								
Operating	9.2	9.5	11.9	12.7	12.9	12.9	12.9	12.9
Capital Equipment	0.4	0.4	0.9	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	9.6	9.9	12.8	13.2	13.4	13.4	13.4	13.4
Direct Personnel	34.5	53.9	45.8	47.8	48.0	48.0	48.0	48.0

Table S4.6 Energy Efficiency and Renewable Energy: Resources by Subprogram (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Policy and Management Program Direction (EH-01)								
Operating	0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	–	–	–	–	–	–	–
Direct Personnel	–	–	–	–	–	–	–	–
International Market Development Program (EH-20)								
Operating	–	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	0.1	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Information and Communications (EH-21)								
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	–	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Total Policy and Management (EH)								
Operating	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Direct Personnel	0.1	1.0	0.9	0.9	0.9	0.9	0.9	0.9
Total Energy Efficiency and Renewable Energy								
Operating	17.5	18.4	23.2	25.4	24.6	24.6	24.6	24.6
Capital Equipment	0.4	0.5	1.9	1.1	1.0	1.0	1.0	1.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	17.9	18.9	25.1	26.5	25.6	25.6	25.6	25.6
Direct Personnel	70.4	105.5	104.5	112.2	104.5	104.5	104.5	104.5

Table S4.7 Fossil Energy: Resources by Subprogram ($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Coal Preparation (AA-10)								
Operating	0.2	0.3	0.5	0.8	1.0	1.0	1.0	1.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	0.3	0.5	0.8	1.0	1.0	1.0	1.0
Direct Personnel	0.3	2.5	2.9	5.1	6.1	6.1	6.1	6.1
Advanced Research and Technology Development (AA-15)								
Operating	1.5	0.9	1.1	1.2	1.2	1.2	1.2	1.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.5	0.9	1.1	1.2	1.2	1.2	1.2	1.2
Direct Personnel	5.1	9.3	5.3	5.6	5.4	5.3	5.3	5.3
Advanced Cleaned Power Systems (AA-20)								
Operating	0.6	0.4	0.5	0.6	0.6	0.6	0.6	0.6
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.6	0.4	0.5	0.6	0.6	0.6	0.6	0.6
Direct Personnel	3.8	1.8	2.4	2.7	2.7	2.7	2.7	2.7
Total Coal (AA)								
Operating	2.3	1.6	2.1	2.6	2.8	2.8	2.8	2.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.3	1.6	2.1	2.6	2.8	2.8	2.8	2.8
Direct Personnel	9.2	13.6	10.6	13.4	14.2	14.1	14.1	14.1
Gas Utilization (AB-05)								
Operating	0.9	0.4	0.4	0.2	0.2	0.2	0.2	0.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.9	0.4	0.4	0.2	0.2	0.2	0.2	0.2
Direct Personnel	1.5	3.7	1.8	0.7	0.7	0.7	0.7	0.7

Table S4.7 Fossil Energy: Resources by Subprogram (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Fuel Cells (AB-45)								
Operating	0.7	0.9	1.1	1.1	1.1	1.1	1.1	1.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.7	0.9	1.1	1.1	1.1	1.1	1.1	1.1
Direct Personnel	3.9	3.9	4.8	5.1	5.1	5.1	5.1	5.1
Total Gas (AB)								
Operating	1.6	1.3	1.5	1.3	1.3	1.3	1.3	1.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1.6	1.3	1.5	1.3	1.3	1.3	1.3	1.3
Direct Personnel	5.4	7.6	6.6	5.8	5.8	5.8	5.8	5.8
Oil Technology Recovery (AC-10)								
Operating	1.1	0.9	0.9	0.6	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.1	0.9	0.9	0.6	0.1	0.1	0.1	0.1
Direct Personnel	2.0	6.8	6.0	3.6	3.6	3.6	3.6	3.6
Total Petroleum (AC)								
Operating	1.1	0.9	0.9	0.6	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	1.1	0.9	0.9	0.6	0.1	0.1	0.1	0.1
Direct Personnel	2.0	6.8	6.0	3.6	3.6	3.6	3.6	3.6
Natural Gas and Electricity (AU-02)								
Operating	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	3.8	1.9	0.7	0.6	0.6	0.6	0.6	0.6
Magnetohydrodynamics (AW-05)								
Operating	–	0.1	0.1	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	0.1	0.1	–	–	–	–	–
Direct Personnel	0.1	0.2	0.1	–	–	–	–	–

Table S4.7 Fossil Energy: Resources by Subprogram (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Total Fossil Energy								
Operating	5.3	4.0	4.7	4.6	4.3	4.3	4.3	4.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.3	4.0	4.7	4.6	4.3	4.3	4.3	4.3
Direct Personnel	20.5	30.1	24.0	23.4	24.2	24.1	24.1	24.1

Table S4.8 Fissile Materials Disposition ($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Fissile Materials Disposition (GA)								
Operating	0.9	1.7	1.7	1.8	1.8	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.9	1.7	1.7	1.8	1.8	–	–	–
Direct Personnel	5.0	7.8	8.4	8.4	8.4	–	–	–

Table S4.9 Defense Programs: Resources by Subprogram ($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Other Weapons Activities (GB)								
Operating	–	–	0.2	0.2	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	0.2	0.2	–	–	–	–
Direct Personnel	1.3	0.3	0.4	0.6	–	–	–	–
Weapons Activities (DP)								
Operating	1.9	0.8	1.4	1.2	1.1	1.1	1.1	1.1
Capital Equipment	–	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	–	–	–	–	–	–	–	–
Total	1.9	0.9	1.5	1.3	1.2	1.2	1.2	1.2
Direct Personnel	11.1	7.3	10.1	5.8	5.3	5.3	5.3	5.3
Total Defense Programs								
Operating	1.9	0.8	1.6	1.4	1.1	1.1	1.1	1.1
Capital Equipment	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1.9	0.9	1.7	1.5	1.2	1.2	1.2	1.2
Direct Personnel	12.4	7.6	10.5	6.4	5.3	5.3	5.3	5.3

Table S4.10 Nonproliferation and National Security: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Nonproliferation and Verification R&D (GC)								
Operating	2.0	1.6	2.1	2.2	2.3	2.2	2.2	2.2
Capital Equipment	–	0.1	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	2.0	1.7	2.1	2.2	2.3	2.2	2.2	2.2
Direct Personnel	7.4	11.0	9.5	10.0	9.9	9.7	9.7	9.7
Nuclear Safeguards and Security (GD)								
Operating	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Direct Personnel	0.5	3.1	1.5	1.3	0.7	0.7	0.7	0.7
Arms Control and Nonproliferation (GJ)								
Operating	8.5	11.3	12.8	11.7	11.6	11.8	11.8	11.8
Capital Equipment	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Construction	–	–	–	–	–	–	–	–
Total	8.9	11.6	13.1	12.0	11.9	12.1	12.1	12.1
Direct Personnel	33.7	46.4	50.6	45.7	44.8	44.7	44.7	44.7
Emergency Preparedness (NB)								
Operating	–	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	0.7	–	–	–	–	–	–	–
Emergency Management (ND)								
Operating	0.1	0.2	0.4	0.3	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	0.2	0.4	0.3	0.1	0.1	0.1	0.1
Direct Personnel	0.2	1.6	2.3	2.1	0.5	0.5	0.5	0.5

Table S4.10 Nonproliferation and National Security: Resources by Subprogram (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Nonproliferation and National Security Program Direction (NN)								
Operating	–	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	–	0.5	0.1	–	–	–	–	–
Intelligence (NT)								
Operating	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2
Direct Personnel	2.2	2.6	1.8	1.5	1.5	1.0	1.0	1.0
Total Nonproliferation and National Security								
Operating	11.2	13.6	15.8	14.7	14.4	14.4	14.4	14.4
Capital Equipment	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	11.6	14.0	16.1	15.0	14.7	14.7	14.7	14.7
Direct Personnel	44.7	65.2	65.8	60.6	57.4	56.6	56.6	56.6

Table S4.11 Environmental Management: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Environmental Restoration and Waste Management — Defense (EW)								
Operating	27.1	20.8	15.7	12.4	12.4	12.4	12.4	12.4
Capital Equipment	0.4	0.3	0.2	0.1	0.1	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	27.5	21.1	15.9	12.5	12.5	12.4	12.4	12.4
Direct Personnel	139.6	105.2	78.0	60.8	20.4	20.4	20.4	20.4
Environmental Restoration and Waste Management — Non-Defense (EX)								
Operating	26.2	28.9	24.5	24.5	20.6	18.6	18.6	18.6
Capital Equipment	0.1	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Construction	-0.8	1.1	–	–	–	–	–	–
General Plant Projects	1.6	0.3	–	–	–	–	–	–
Total	27.1	30.6	24.7	24.7	20.8	18.8	18.8	18.8
Direct Personnel	91.6	135.8	111.7	103.2	93.7	86.3	86.3	86.3
Total Environmental Management								
Operating	53.3	49.7	40.2	36.9	33.0	31.0	31.0	31.0
Capital Equipment	0.5	0.6	0.4	0.3	0.3	0.2	0.2	0.2
Construction	-0.8	1.1	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	1.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Total	54.6	51.7	40.6	37.2	33.3	31.2	31.2	31.2
Direct Personnel	231.2	241.0	189.7	164.0	114.1	106.7	106.7	106.7

Table S4.12 Environment, Safety, and Health: Resources by Subprogram
($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Environment, Safety, and Health — Non-Defense (HC)								
Operating	2.3	1.5	1.7	1.7	1.7	1.7	1.7	1.7
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	2.3	1.5	1.7	1.7	1.7	1.7	1.7	1.7
Direct Personnel	9.1	12.2	9.3	8.9	8.9	8.9	8.9	8.9
Environment, Safety, and Health — Defense (HD-10)								
Operating	–	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	0.1	0.4	0.1	–	–	–	–	–
Total Environment, Safety, and Health								
Operating	2.3	1.5	1.7	1.7	1.7	1.7	1.7	1.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.3	1.5	1.7	1.7	1.7	1.7	1.7	1.7
Direct Personnel	9.2	12.6	9.4	8.9	8.9	8.9	8.9	8.9

Table S4.13 Civilian Radioactive Waste Management ($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Waste Management System (DB)								
Operating	0.1	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	–	–	–	–	–	–	–
Direct Personnel	3.3	0.4	–	–	–	–	–	–

Table S4.14 Policy, Planning, and Program Evaluation: Resources by Subprogram ($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
International Affairs and Energy Emergencies (NA)								
Operating	–	–	0.1	0.1	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	0.1	0.1	–	–	–	–
Direct Personnel	0.3	–	0.2	0.2	–	–	–	–
Policy, Planning, and Analysis (PE-01)								
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	0.8	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Office of Environmental Analysis (PE-04)								
Operating	0.6	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.6	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Direct Personnel	3.6	3.6	2.4	2.0	1.3	1.3	1.3	1.3
Total Policy, Planning, and Program Evaluation								
Operating	0.7	0.5	0.6	0.6	0.4	0.4	0.4	0.4
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.7	0.5	0.6	0.6	0.4	0.4	0.4	0.4
Direct Personnel	4.7	3.9	2.8	2.4	1.5	1.5	1.5	1.5

Table S4.15 Economic Impact and Diversity ($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Minority Economic Impact Program (WA-50)								
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	2.4	0.9	1.0	0.9	0.9	0.9	0.9	0.9

Table S4.16 Science Education ($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
University and Science Education (KT)								
Operating	2.6	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	2.6	–	–	–	–	–	–	–
Direct Personnel	11.9	7.2	–	–	–	–	–	–

Table S4.17 Work for Other DOE Contractors ($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Operating	25.5	27.0	25.0	25.0	25.0	25.0	25.0	25.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	25.5	27.0	25.0	25.0	25.0	25.0	25.0	25.0
Direct Personnel	64.6	109.0	75.0	74.2	74.2	74.2	74.2	74.2
Transfer to Other DOE Contractors	-11.6	-12.0	-12.0	-10.0	-10.0	-10.0	-10.0	-10.0

Table S4.18 Work for Sponsors Other than DOE ($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
NUCLEAR REGULATORY COMMISSION								
Office of Nuclear Regulatory Research								
Operating	5.3	10.4	9.0	9.0	8.7	8.7	8.7	8.7
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	5.3	10.4	9.0	9.0	8.7	8.7	8.7	8.7
Direct Personnel	22.8	35.5	30.5	30.1	29.0	24.6	24.6	24.6
Office of Nuclear Reactor Regulation								
Operating	0.4	–	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.4	–	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	1.2	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Commission and Staff Offices								
Operating	–	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	–	–	–	–	–	–	–	–
Nuclear Material Safety and Safeguards								
Operating	–	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	–	–	–	–	–	–	–	–
Office of Administration								
Operating	–	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	–	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table S4.18 Work for Sponsors Other than DOE (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Executive Director for Operations and Staff Offices								
Operating	–	–	–	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–
Direct Personnel	–	–	–	–	–	–	–	–
Total Nuclear Regulatory Commission								
Operating	5.7	10.8	9.6	9.6	9.3	9.3	9.3	9.3
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	5.7	10.8	9.6	9.6	9.3	9.3	9.3	9.3
Direct Personnel	24.0	37.2	32.2	31.8	30.7	26.3	26.3	26.3
DEPARTMENT OF DEFENSE								
Strategic Defense Initiative								
Operating	0.2	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	0.2
Direct Personnel	1.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Advanced Research Projects Agency								
Operating	1.3	0.5	0.1	–	–	–	–	–
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.3	0.5	0.1	–	–	–	–	–
Direct Personnel	3.6	4.0	1.0	–	–	–	–	–
Strategic Environmental Research and Development Program (SERDP)								
Operating	0.2	–	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.2	–	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	1.0	–	2.0	2.0	2.0	2.0	2.0	2.0

Table S4.18 Work for Sponsors Other than DOE (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
National Security Agency								
Operating	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1
Direct Personnel	7.3	2.0	2.0	1.0	1.0	1.0	1.0	1.0
U.S. Air Force								
Operating	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Direct Personnel	19.3	11.0	11.0	11.0	11.0	11.0	11.0	11.0
The Joint Staff								
Operating	4.2	1.8	1.0	0.8	0.8	0.8	0.8	0.8
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	4.2	1.8	1.0	0.8	0.8	0.8	0.8	0.8
Direct Personnel	21.0	8.0	5.0	5.0	5.0	5.0	5.0	5.0
U.S. Army								
Operating	13.7	17.3	13.0	13.0	13.0	13.0	13.0	13.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	13.7	17.3	13.0	13.0	13.0	13.0	13.0	13.0
Direct Personnel	69.0	80.0	65.0	65.0	65.0	65.0	65.0	65.0
U.S. Navy								
Operating	0.5	1.0	0.8	0.5	0.5	0.5	0.5	0.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.5	1.0	0.8	0.5	0.5	0.5	0.5	0.5
Direct Personnel	1.4	2.5	2.0	1.0	1.0	1.0	1.0	1.0
Defense Nuclear Agency								
Operating	1.4	2.1	0.9	0.6	0.6	0.6	0.6	0.6
Capital Equipment	–	0.5	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.4	2.6	0.9	0.6	0.6	0.6	0.6	0.6
Direct Personnel	8.9	11.8	7.1	6.0	6.0	6.0	6.0	6.0

Table S4.18 Work for Sponsors Other than DOE (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
U.S. Marines								
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	–	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Secretary of Defense								
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	–	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total Department of Defense								
Operating	24.8	25.5	19.1	18.0	18.0	18.0	18.0	18.0
Capital Equipment	0.0	0.5	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	24.8	26.0	19.1	18.0	18.0	18.0	18.0	18.0
Direct Personnel	132.9	121.4	97.2	93.1	93.1	93.1	93.1	93.1
OTHER FEDERAL AGENCIES								
Environmental Protection Agency								
Operating	0.5	1.6	1.3	1.3	1.3	1.3	1.3	1.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.5	1.6	1.3	1.3	1.3	1.3	1.3	1.3
Direct Personnel	3.3	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Arms Control and Disarmament Agency								
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	0.1	0.4	0.3	0.3	0.3	0.3	0.3	0.3

Table S4.18 Work for Sponsors Other than DOE (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
National Aeronautics and Space Administration								
Operating	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Federal Emergency Management Agency								
Operating	5.2	4.6	4.5	4.5	4.5	4.5	4.5	4.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	5.2	4.6	4.5	4.5	4.5	4.5	4.5	4.5
Direct Personnel	23.9	23.0	23.0	23.0	23.0	23.0	23.0	23.0
Department of State (International Atomic Energy Agency)								
Operating	3.3	1.9	1.9	2.0	2.0	2.0	2.0	2.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	3.3	1.9	1.9	2.0	2.0	2.0	2.0	2.0
Direct Personnel	9.9	11.2	11.2	11.2	11.2	11.2	11.2	11.2
Health and Human Services								
Operating	0.1	0.9	0.8	0.8	0.8	0.8	0.8	0.8
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	0.1	0.9	0.8	0.8	0.8	0.8	0.8	0.8
Direct Personnel	0.2	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Department of Transportation								
Operating	–	1.6	2.0	2.0	2.0	2.0	2.0	2.0
Capital Equipment	–	0.2	0.4	0.8	0.8	0.8	0.8	0.8
Construction	–	–	–	–	–	–	–	–
Total	–	1.8	2.4	2.8	2.8	2.8	2.8	2.8
Direct Personnel	4.7	8.0	9.5	9.5	9.5	9.5	9.5	9.5

Table S4.18 Work for Sponsors Other than DOE (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Department of Agriculture								
Operating	8.6	4.2	4.8	4.8	4.8	4.8	4.8	4.8
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	8.6	4.2	4.8	4.8	4.8	4.8	4.8	4.8
Direct Personnel	24.4	20.0	22.0	22.0	22.0	22.0	22.0	22.0
Department of Commerce								
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	0.5	0.5	0.5	0.5	0.5	0.5
National Science Foundation								
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	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Other Agencies								
Operating	1.6	6.6	4.5	4.5	4.5	4.5	4.5	4.5
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.6	6.6	4.5	4.5	4.5	4.5	4.5	4.5
Direct Personnel	8.4	33.0	26.0	26.0	26.0	26.0	26.0	26.0
Total Other Federal Agencies								
Operating	19.6	21.9	20.3	20.4	20.4	20.4	20.4	20.4
Capital Equipment	0.0	0.2	0.4	0.8	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	19.6	22.1	20.7	21.2	21.2	21.2	21.2	21.2
Direct Personnel	76.1	111.3	107.7	107.7	107.7	107.7	107.7	107.7

Table S4.18 Work for Sponsors Other than DOE (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
NONFEDERAL ORGANIZATIONS								
Electric Power Research Institute								
Operating	1.6	0.5	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	1.6	0.5	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	9.9	2.6	1.5	1.5	1.5	1.5	1.5	1.5
Gas Research Institute								
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	3.1	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Private Firms								
Operating	7.8	15.1	16.5	16.0	16.0	16.0	16.0	16.0
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	7.8	15.1	16.5	16.0	16.0	16.0	16.0	16.0
Direct Personnel	30.9	64.0	65.0	65.0	65.0	65.0	65.0	65.0
Universities and State and Local Governments								
Operating	4.8	1.1	1.3	1.3	1.3	1.3	1.3	1.3
Capital Equipment	–	–	–	–	–	–	–	–
Construction	–	–	–	–	–	–	–	–
Total	4.8	1.1	1.3	1.3	1.3	1.3	1.3	1.3
Direct Personnel	23.9	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Total Nonfederal Organizations								
Operating	14.2	16.8	18.2	17.7	17.7	17.7	17.7	17.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14.2	16.8	18.2	17.7	17.7	17.7	17.7	17.7
Direct Personnel	67.8	73.3	73.2	73.2	73.2	73.2	73.2	73.2

Table S4.18 Work for Sponsors Other than DOE (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
TOTAL WORK FOR SPONSORS OTHER THAN DOE								
Operating	64.3	75.0	67.2	65.7	65.4	65.4	65.4	65.4
Capital Equipment	0.0	0.7	0.4	0.8	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	64.3	75.7	67.6	66.5	66.2	66.2	66.2	66.2
Direct Personnel	300.8	343.2	310.3	305.8	304.7	300.3	300.3	300.3

Table S4.19 Funding by Assistant Secretarial Office ($ in millions BA, personnel in FTE)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
DOE WORK								
Table S4.3 — Nuclear Energy, Science and Technology								
Operating	95.8	89.9	108.7	108.5	107.5	105.9	105.7	104.9
Capital Equipment	3.0	1.0	1.0	2.5	2.5	2.5	2.5	2.5
Construction	1.7	2.7	1.5	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	1.5	1.3	1.3	1.3	0.5	0.5	0.5
Total	100.5	95.1	112.5	112.3	111.3	108.9	108.7	107.9
Direct Personnel	473.1	473.7	535.8	522.7	510.2	496.5	483.5	468.5
Table S4.4 — Energy Research								
Operating	177.6	169.4	179.2	206.4	214.2	214.2	214.2	214.2
Capital Equipment	18.3	10.7	14.6	21.1	21.8	21.3	20.8	20.8
General Purpose Equipment	2.0	1.9	2.2	3.3	3.5	3.7	3.9	4.2
Construction	7.8	3.5	3.5	0.0	0.0	0.0	0.0	0.0
General Plant Projects	5.7	4.8	7.4	7.8	8.0	8.3	8.6	8.9
Subtotal	211.4	190.3	206.9	138.6	247.5	247.5	247.5	248.1
Inventory	-1.3	0.0	0.2	0.5	0.5	0.5	0.5	0.5
Multiprogram Energy Laboratories — Facilities Support Program	7.5	4.8	17.2	0.0	0.0	0.0	0.0	0.0
Total Energy Research	217.6	195.1	224.3	239.1	248.0	248.0	248.0	248.6
Direct Personnel	919.2	954.7	996.1	1040.2	1049.8	1048.5	1048.5	1048.5
Table S4.5 — Federal Energy Regulatory Commission								
Operating	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	0.2	0.7	0.6	0.6	0.6	0.6	0.6	0.6
Table S4.6 — Energy Efficiency and Renewable Energy								
Operating	17.5	18.4	23.2	25.4	24.6	24.6	24.6	24.6
Capital Equipment	0.4	0.5	1.9	1.1	1.0	1.0	1.0	1.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	17.9	18.9	25.1	26.5	25.6	25.6	25.6	25.6
Direct Personnel	70.4	105.5	104.5	112.2	104.5	104.5	104.5	104.5

Table S4.19 Funding by Assistant Secretarial Office (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Table S4.7 — Fossil Energy								
Operating	5.3	4.0	4.7	4.6	4.3	4.3	4.3	4.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.3	4.0	4.7	4.6	4.3	4.3	4.3	4.3
Direct Personnel	20.5	30.1	24.0	23.4	24.2	24.1	24.1	24.1
Table S4.8 — Fissile Materials Disposition								
Operating	0.9	1.7	1.7	1.8	1.8	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	0.9	1.7	1.7	1.8	1.8	0.0	0.0	0.0
Direct Personnel	5.0	7.8	8.4	8.4	8.4	0.0	0.0	0.0
Table S4.9 — Defense Programs								
Operating	1.9	0.8	1.6	1.4	1.1	1.1	1.1	1.1
Capital Equipment	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1.9	0.9	1.7	1.5	1.2	1.2	1.2	1.2
Direct Personnel	12.4	7.6	10.5	6.4	5.3	5.3	5.3	5.3
Table S4.10 — Nonproliferation and National Security								
Operating	11.2	13.6	15.8	14.7	14.4	14.4	14.4	14.4
Capital Equipment	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	11.6	14.0	16.1	15.0	14.7	14.7	14.7	14.7
Direct Personnel	44.7	65.2	65.8	60.6	57.4	56.6	56.6	56.6
Table S4.11 — Environmental Management								
Operating	53.3	49.7	40.2	36.9	33.0	31.0	31.0	31.0
Capital Equipment	0.5	0.6	0.4	0.3	0.3	0.2	0.2	0.2
Construction	-0.8	1.1	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	1.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Total	54.6	51.7	40.6	37.2	33.3	31.2	31.2	31.2
Direct Personnel	231.2	241.0	189.7	164.0	114.1	106.7	106.7	106.7

Table S4.19 Funding by Assistant Secretarial Office (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Table S4.12 — Environment, Safety, and Health								
Operating	2.3	1.5	1.7	1.7	1.7	1.7	1.7	1.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.3	1.5	1.7	1.7	1.7	1.7	1.7	1.7
Direct Personnel	9.2	12.6	9.4	8.9	8.9	8.9	8.9	8.9
Table S4.13 — Civilian Radioactive Waste Management								
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	3.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Table S4.14 — Policy, Planning, and Program Evaluation								
Operating	0.7	0.5	0.6	0.6	0.4	0.4	0.4	0.4
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.7	0.5	0.6	0.6	0.4	0.4	0.4	0.4
Direct Personnel	4.7	3.9	2.8	2.4	1.5	1.5	1.5	1.5
Table S4.15 — Economic Impact and Diversity								
Operating	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	2.4	0.9	1.0	0.9	0.9	0.9	0.9	0.9
Table S4.16 — Science Education								
Operating	2.6	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	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	11.9	7.2	0.0	0.0	0.0	0.0	0.0	0.0

Table S4.19 Funding by Assistant Secretarial Office (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Table S4.17 — Work for Other DOE Contractors								
Operating	25.5	27.0	25.0	25.0	25.0	25.0	25.0	25.0
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	25.5	27.0	25.0	25.0	25.0	25.0	25.0	25.0
Direct Personnel	64.6	109.0	75.0	74.2	74.2	74.2	74.2	74.2
TOTAL WORK FOR DOE PROGRAMS								
Operating	395.3	376.8	402.7	427.3	428.3	422.9	422.7	421.9
Capital Equipment	22.6	13.3	18.3	25.4	26.0	25.4	24.9	24.9
General Purpose Equipment	2.0	1.9	2.2	3.3	3.5	3.7	3.9	4.2
Construction	8.7	7.3	5.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	7.3	6.6	8.7	9.1	9.3	8.8	9.1	9.4
Subtotal	435.9	405.9	436.9	465.1	467.1	460.8	460.6	460.4
Inventory	-1.3	0.0	0.2	0.5	0.5	0.5	0.5	0.5
Multiprogram Energy Laboratories — Facilities Support Program	7.5	4.8	17.2	0.0	0.0	0.0	0.0	0.0
Total	442.1	410.7	454.3	465.6	467.6	461.3	461.1	460.9
Table S4.18 — WORK FOR SPONSORS OTHER THAN DOE								
Nuclear Regulatory Commission								
Operating	5.7	10.8	9.6	9.6	9.3	9.3	9.3	9.3
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	5.7	10.8	9.6	9.6	9.3	9.3	9.3	9.3
Department of Defense								
Operating	24.8	25.5	19.1	18.0	18.0	18.0	18.0	18.0
Capital Equipment	0.0	0.5	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	24.8	26.0	19.1	18.0	18.0	18.0	18.0	18.0

Table S4.19 Funding by Assistant Secretarial Office (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Other Federal Agencies								
Operating	19.6	21.9	20.3	20.4	20.4	20.4	20.4	20.4
Capital Equipment	0.0	0.2	0.4	0.8	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	19.6	22.1	20.7	21.2	21.2	21.2	21.2	21.2
Nonfederal Organizations								
Operating	14.2	16.8	18.2	17.7	17.7	17.7	17.7	17.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14.2	16.8	18.2	17.7	17.7	17.7	17.7	17.7
TOTAL WORK FOR SPONSORS OTHER THAN DOE								
Operating	64.3	75.0	67.2	65.7	65.4	65.4	65.4	65.4
Capital Equipment	0.0	0.7	0.4	0.8	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	64.3	75.7	67.6	66.5	66.2	66.2	66.2	66.2
TOTAL OPERATING FUNDING	459.6	451.8	469.9	493.0	493.7	488.3	488.1	487.3
TOTAL CAPITAL EQUIPMENT	22.6	14.0	18.7	26.2	26.8	26.2	25.7	25.7
TOTAL CONSTRUCTION	8.7	7.3	5.0	0.0	0.0	0.0	0.0	0.0
TOTAL INVENTORY	-1.3	0.0	0.2	0.5	0.5	0.5	0.5	0.5
TOTAL GENERAL PURPOSE EQUIPMENT	2.0	1.9	2.2	3.3	3.5	3.7	3.9	4.2
TOTAL GENERAL PLANT PROJECTS	7.3	6.6	8.7	9.1	9.3	8.8	9.1	9.4
TOTAL MULTIPROGRAM ENERGY LABORATORIES — FACILITIES SUPPORT PROGRAM	7.5	4.8	17.2	0.0	0.0	0.0	0.0	0.0
GRAND TOTAL LABORATORY FUNDING	506.4	486.4	521.9	532.1	533.8	527.5	527.3	527.1

Table S4.19 Funding by Assistant Secretarial Office (Cont.)

	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
TOTAL PROPOSED PROJECTS								
TOTAL PROGRAM CONSTRUCTION	0.0	0.0	0.0	8.9	15.5	6.0	6.0	6.0
TOTAL MULTIPROGRAM ENERGY LABORATORIES — FACILITIES SUPPORT PROGRAM	0.0	0.0	0.0	16.9	29.7	35.2	17.7	25.1
GRAND TOTAL PROJECTED FUNDING	506.4	486.4	521.9	557.9	579.0	568.7	551.0	558.2

Table S4.20 Subcontracting and Procurement ($ in millions)

	FY 1995	FY 1996	FY 1997[a]
Subcontracts and Procurements from Universities	6.0	7.5	6.4
All Other Subcontracts and Procurements	209.0	191.0	150.4
Transfer to Other DOE Facilities	1.7	1.0	3.2
Total Subcontracts and Procurements	216.7	156.8	160.0

[a]Estimate.

Table S4.21 Small and Disadvantaged Business Procurement ($ in millions)

	FY 1995	FY 1996	FY 1997[a]
Procurements from Small and Disadvantaged Businesses	19.1	10.4	8.0
Percent of Annual Procurement	8.8	6.6	5.0

[a]Estimate.