Office of Science
Executive Budget Summary

The Office of Science (SC) requests $3,151,065,000 for Fiscal Year (FY) 2001in the "Science" appropriation, an increase of $363,438,000 over FY 2000, to invest in thousands of individual research projects at hundreds of research facilities across the U.S., primarily at our national laboratories and research universities. In addition, the FY 2001 request will support: continuing construction of the Spallation Neutron Source; increasing investments in nano-scale science to make significant contributions to the interagency initiative in nano-technology; implementing advanced computational modeling and simulation for DOE's broad scientific challenges; investigating the workings of the microbial cell for DOE applications; improving the utilization of our major scientific user facilities; and updating the skills of our technical workforce. Within the "Energy Supply" appropriation an increase of $702,000 is requested for the Technical Information Management program.

A History of Success:

The National Academy of Sciences has noted that much of U.S. economic growth, quality of life, and security derive from the national investment and leadership in science and technology. In FY 2000, the Department of Energy (DOE) is the third-largest government sponsor of basic research in the U.S., principally through the programs managed by SC. In service to DOE's applied missions in energy resources, national security, and environmental quality, SC programs lead the nation in many areas of the physical and computational sciences and contribute significantly to major advances in biological and environmental research. These programs have extended the frontiers of science and contribute to our economy through achievements such as:

- Supporting the fundamental research of 70 Nobel Laureates, from Enrico Fermi and E.O. Lawrence to Richard Smalley and Paul Boyer;
- Contributing to the development of the current generation of high-energy and high-power-output lithium and lithium-ion batteries through research in nonaqueous electrolytes;
- Enabling treatment of disease and addiction by building on brain-imaging studies based on SC work in Positron Emission Tomography;
- Developing computational ability exceeding one teraflop of sustained performance for DOE research applications;
- Advancing miniaturization through research into nanowires and phenomena such as conductance quantization;
- Advancing the physics of plasmas, a key element in the manufacture of materials coatings, semi-conductors, lighting systems, and waste disposal systems; and
- Discovering quarks, from the original three light ones - up, down and strange - to the heavy ones - charm, beauty, and top. All of the quarks were discovered at DOE laboratories between 1960 and 1995.

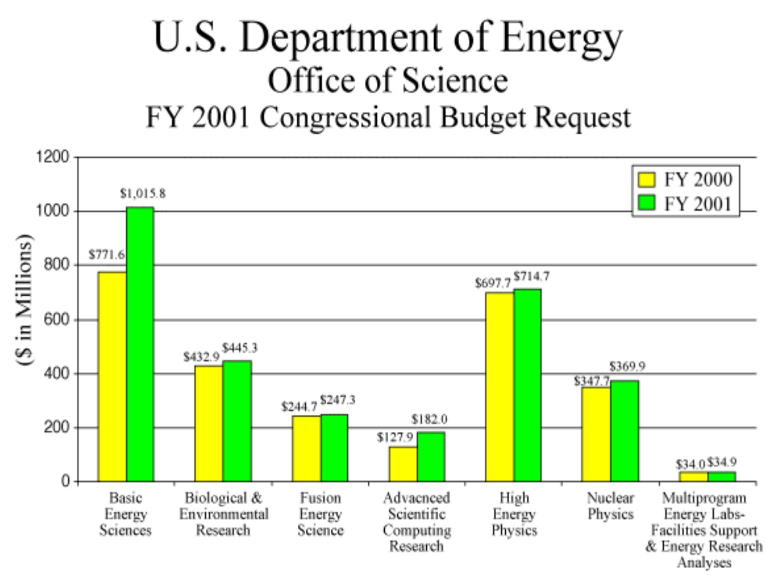

Figure 1

A New Plan for DOE Science:

The 20th century has brought many scientific advances that have resulted in dramatic changes in our standard of living. New opportunities are opening every day as we learn to control matter at the atomic level, develop cleaner new energy sources, simulate that which we cannot easily test in the laboratory, and look deeply into the cosmos to the very origins of matter and energy. At the same time, federal science programs are being called upon to deliver more for less. Managers and scientists must scrutinize their investments and establish priorities more carefully than ever before.

The SC Strategic Plan and Science Portfolio, published in June 1999 and available on the Web at www.sc.doe.gov, are part of a long range planning process to define the goals, objectives, strategies and portfolio of research that will enable DOE to succeed in it's technology driven missions. Bold new questions and intriguing scientific challenges designed to build the scientific foundations for a strong and prosperous nation in the 21st century are contained within the pages of the SC Strategic Plan. The goals of the Strategic Plan are outlined in Figure 2.

Figure 2

The Science Portfolio provides the link between the goals and strategies of the Plan and the research activities within the SC programs. The Portfolio identifies the motivations, activities, accomplishments, and near-term resources for SC's research programs.

Development of the Strategic Plan and Portfolio identified new opportunities in high impact areas of research. Roadmapping efforts are under development to explore the potential of complex systems, carbon sequestration, computational modeling and simulation, and scientific facilities as applied to SC research interests. The roadmaps will identify the steps that are needed to achieve the desired DOE goals.

Implementing the Plan - Priorities:

The FY 2001 budget request, depicted in Figure 1 and Table 1, has a program structure that meets our mission, consistent with departmental goals and strategies. The major SC programs are High Energy and Nuclear Physics, Basic Energy Sciences, Biological and Environmental Research, Advanced Scientific Computing Research, and Fusion Energy Sciences.

The five goals contained in the Strategic Plan provide a framework for current programs and a platform for future efforts. FY 2001 initiatives and priorities are detailed below.

Nanoscale Discovery - The principal missions of the DOE in Energy, Defense and the Environment will benefit greatly from future developments in nanoscale science, engineering and technology. The SC research program has a strong focus on nanoscale discovery, the development of fundamental scientific understanding, and the conversion of these into useful technological solutions.

A key challenge in nanoscience is to understand how deliberate tailoring of materials on the nanoscale can lead to novel properties and new functionalities. Examples include: the addition of aluminum oxide nanoparticles that convert aluminum metal into a material with wear resistance equal to that of the best bearing steel; novel chemical properties of nanocrystals that show promise as photocatalysts to speed the breakdown of toxic wastes; and, meso-porous structures integrated with micromachined components that are used to produce high-sensitivity and highly selective chip-based detectors of chemical warfare agents. These and other nanostructures are already recognized as likely components of 21st century optical communications, printing, computing, chemical sensing, and energy conversion technologies.

The DOE is well prepared to make major contributions to developing nanoscale scientific understanding and ultimately nanotechnologies through its research programs and its materials characterization, synthesis, in-situ diagnostic, and computing capabilities. The DOE and its national laboratories maintain a large array of major scientific user facilities that are ideally suited to nanoscience discovery and to developing a fundamental understanding of nanoscale processes.

FY 2001 funding is being requested as part of the proposed multiagency National Nanotechnology effort. New efforts are proposed to attain a fundamental scientific understanding of nanoscale phenomena; to achieve the ability to design and synthesize materials at the atomic level to produce materials with desired properties and functions; to attain a fundamental understanding of the processes by which living organisms create materials and functional complexes to serve as a guide and a benchmark by which to measure our progress in synthetic design and synthesis; and to develop experimental characterization tools and theory/modeling/simulation tools necessary to drive the nanoscale revolution.

The synergy of these DOE assets, in partnership with universities and industry, will provide the best opportunity for nanoscience discoveries to be converted rapidly into technological advances that will meet a variety of national needs and enable the U.S. to reap the benefits of an emerging technological revolution.

Non-Defense Scientific Supercomputing— Computational modeling and simulation is one of the most significant developments in the practice of scientific research in the 20th century. Scientific and engineering simulation has dramatically advanced our understanding of nature and has been used to gain insights into the behavior of such complex natural and engineered systems as the weather, materials properties, turbulence and fluid flow, and high-density plasmas.

Dramatic advances in computer technologies in the past decade have set the stage for major advancements in computational modeling and simulation capability. Within the next five years, high-performance computing systems capability will increase by a factor of 1000 (to terascale computing). These computing systems will enable scientists to predict the behavior of a broad range of complex natural and engineered systems at a level of accuracy and detail never before achieved. This will have an enormous impact on broad classes of scientific research and will ultimately address DOE's most demanding, mission-driven challenges.

DOE has a long history of accomplishment in scientific computing. As a result, the Department has served as the proving ground for new computer technologies—subjecting these technologies to the demands that only its most computationally intensive simulations could provide. In 1974, the Department established the first civilian supercomputer center for a national scientific community, the National Magnetic Fusion Energy Computing Center, which became a model for centers established a decade later by NSF and other agencies.

DOE's achievements in software for scientific computing are equally impressive. DOE led the transition from the vector supercomputers of the 1970s and 1980s to the massively parallel supercomputers of today, providing much of the basic software required to use the massively parallel supercomputers. Many of the scientific simulation software packages for massively parallel supercomputers were developed by DOE, a fact recognized by periodic awards from the supercomputing community.

To realize the advances promised by terascale computing, SC will focus on: the development of: a new generation of computational modeling and simulation software that takes full advantage of terascale computers; and the terascale systems infrastructure and software needed to make terascale computers usable for advanced scientific simulation.

The proposed investments support the recommendations outlined in the report by the President's Information Technology Advisory Committee (PITAC) and take advantage of the capabilities being developed in the Accelerated Strategic Computing Initiative (ASCI) in the Office of Defense Programs for DOE's "Stockpile Stewardship Program."

Simulation of complex systems requires integration of a broad range of physical, chemical and biological processes, knowledge of which can cut across research programs in the Office of Science. In addition, terascale computers pose problems far more complex than those encountered with vector supercomputers, necessitating close collaboration between disciplinary computational scientists, computer scientists, and applied mathematicians. The formation of integrated, multidisciplinary teams is the key to success, an approach that DOE has successfully exploited in many past projects, ranging from the development of new accelerators to the establishment of the fundamental basis for understanding climate change.

Spallation Neutron Source (SNS) - As the needs of our high technology society have changed, so have the ways in which we develop new materials to meet these needs. It has become increasingly important to create new materials that perform under severe conditions and yet are stronger, lighter and cheaper. Major research facilities are used to understand and "engineer" materials at the atomic level so that they have improved macroscopic properties and perform better in new applications. The SNS is a next-generation facility for just this kind of research.

The SNS project will provide a short-pulse spallation neutron source for neutron scattering and related research in broad areas of the physical, chemical, materials, biological and medical sciences. When completed in 2006, the SNS will be more than ten times more powerful than the most powerful neutron source now in existence. The total project cost for the SNS is $1,440,000,000.

Neutron scattering will play a role in all forms of materials and design, including the development of smaller and faster electronic devices; lightweight alloys, plastics and polymers for transportation and other applications; magnetic materials for more effective motors and for improved magnetic storage capacity; and new drugs for medical care.

Researchers from academia, the national laboratories and industry will use the SNS to conduct research. Both basic and applied research will be conducted as will technology development in the fields of condensed matter physics, materials sciences, magnetic materials, polymers and complex fluids, chemistry, biology, and engineering. It is anticipated that 1,000-2,000 scientists and engineers will utilize the SNS each year and that it will meet the nation's need for neutron research well into the 21st century.

The SNS is a partnership between five DOE laboratories [Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), Los Alamos National Laboratory (LANL), Oak

Ridge National Laboratory (ORNL)] that takes advantage of the specialized technical capabilities of each laboratory.

The project is centrally managed from the SNS Project Office at ORNL under the leadership of an experienced Project Executive Director, who has primary authority over the project staff at all five laboratories.

Scientific Facilities Utilization - The FY 2001 budget request strongly supports Scientific Facilities Utilization in the following programs: Basic Energy Sciences, High Energy Physics, Nuclear Physics, Fusion Energy Sciences, Biological and Environmental Research, and Advanced Scientific Computing Research.

Each year, over 15,000 university, industry, and government-sponsored scientists conduct cutting edge experiments at these particle accelerators, high-flux neutron sources, synchrotron radiation light sources, and other specialized facilities. The user community continues to be pleased with the service provided to them by the SC scientific facilities, as evidenced by their many letters of support and by the positive results of surveys conducted at the facilities.

In FY 2001, operating budgets are increasing at the synchrotron radiation light sources and the neutron scattering facilities to provide increased operating time and support for users and to fabricate instruments and beamlines to serve the large and growing user community at these facilities.

Large Hadron Collider (LHC) - The foremost high energy physics research facility of the next decade will be the LHC at CERN, the European Laboratory for Particle Physics. The primary physics goals of the LHC will impact our understanding of the origin of mass through studies of the elusive "Higgs" particle, exploration of the structure and interactions of quarks, and unanticipated phenomena. The High Energy Physics Advisory Panel (HEPAP) strongly endorsed participation in the LHC to provide U.S. access to the high energy frontier in order to maintain the U.S. as a world leader in this fundamental area of science.

DOE and the National Science Foundation (NSF) have entered into an agreement with CERN about contributions to the LHC accelerator and detectors as part of U.S. participation in the LHC program. This agreement, signed in 1997, provides access for U.S. scientists to the next decade's premier high energy physics facility. Under the agreement, the DOE will contribute $450 million ($250 million for the detectors and $200 million for the accelerator) to the LHC effort over the period FY 1996 through FY 2004. The total cost of the LHC is estimated at about $6 billion.

SC has conducted cost and schedule reviews of the U.S. funded components of the LHC project. All of the reviews concluded that the costs are properly estimated and the schedule is feasible.

The agreement with CERN also provides for U.S. involvement in the management of the project and participation in key management committees. This will enable the U.S. to monitor the progress of the project and to ensure full access for U.S. scientists to the research opportunities of the facility.

Fermilab is the lead laboratory for the accelerator portion of the U.S. LHC program, which it will execute in cooperation with BNL and LBNL. BNL is the host laboratory for the ATLAS detector, which also involves ANL, LBNL, and 28 university groups.

Fermilab is the host laboratory for the Compact Muon Solenoid (CMS) detector portion of the project, including BNL, LANL, and 33 university groups. Cost and schedule baselines have been reviewed and validated for each of the three portions of the project, and management systems are in place to monitor progress against baselines.

Life Sciences – Beginning in FY 2001, the Office of Science will support two key areas in the life sciences — the Microbial Cell Project and Biomedical Engineering.

The goal of the Microbial Cell Project is to develop a comprehensive understanding of the complete workings of a microbial cell. Examples include: DNA sequence; the identification of all of the microbe's genes; the production of all of the proteins whose assembly instructions are contained in the genes; and the complex interaction of the genes and proteins in a cell that give the microbe its life and its unique characteristics and behaviors.

The key scientific challenges are far greater than simply understanding how individual genes and proteins work. We need to understand how genes and proteins are regulated in a coordinated manner and how they are integrated into a functional, interactive cell. The Microbial Cell Project will challenge scientists to go beyond the leveraging of tools and technologies for high throughput DNA sequencing. This will require high throughput approaches for determining the structure and function of proteins, computational biology and bioinformatics resources; the development and use of sophisticated imaging and analytical sensing technologies; and novel approaches to modeling and analyzing complex systems.

This information will address DOE needs in energy use and production, bioremediation, and carbon sequestration, and will provide exciting, new, and previously unavailable information to the entire biological community.

The Biomedical Engineering Program capitalizes on DOE's unique resources and expertise in the biological, physical, chemical and engineering sciences to develop new research opportunities for technological advancement against problems dealing with human health. This activity will: advance fundamental concepts; create knowledge from the molecular to the organ systems level; and develop innovative biologics, materials, processes, implants, devices, and informatics systems to be used for the prevention, diagnosis, and treatment of disease. DOE's Biomedical Engineering Program will complement other Federal programs by supporting early stage research at the national laboratories that cannot be funded by other Agencies.

Scientific and Technical Workforce Retention and Recruitment – During 1999, DOE conducted a systematic analysis of critical staffing needs within the context of current and projected R&D program missions. As a result, staffing shortfalls were identified, especially in scientific and technical disciplines. The Department will focus on building and sustaining a talented and diverse workforce of R&D Technical Managers through innovative recruitment strategies, retention incentives, comprehensive training and development programs, and succession planning.

The Office of Science, utilizing Program Direction funds, will recruit experienced scientists and related support staff in areas important to the Department's science mission. Other key activities to be supported include motivating and retaining highly skilled, top-performing technical managers, and the training of new and current scientists.

The Number of Graduate Students and Post Doctoral Investigators Supported

	Research Support	at User Facilities
FY 1999	6,550	4,840

Recent Office of Science Successes:

- Contributed 16% of the first one billion base pairs of human DNA sequence deposited in public databases by the human genome project.
- Advanced theoretical physics by demonstrating and verifying that all known "string" theories are equivalent.

- Developed and made publicly available the numerical linear algebra libraries on which today's high performance computers rely. These libraries represent decades of research.
- Observed the formation of two new chemical elements (numbers 116 and 118) at the LBNL's 88-Inch Cyclotron.
- Developed a rapid, efficient, self-assembly process for making "nanocomposite" materials, clearing the way for new materials with unprecedented mechanical properties.
- Advanced our understanding of tearing and reconnection in magnetic fields. This is important in many areas of fusion science, including understanding the eruptions of energetic bursts from the surface of the sun.

In addition, hundreds of principal investigators funded by SC have won dozens of major prizes and awards sponsored by the President, the Department, the National Academy of Sciences (NAS), the National Academy of Engineering, and the major professional societies.

Major Program Activities for FY 2001:

The **Basic Energy Sciences** (BES) program is one of the nation's major sponsors of fundamental research in broad areas of materials sciences, chemical sciences, geosciences, plant and microbial sciences, and engineering sciences. This program encompasses more than 2,400 researchers in 200 institutions and 17 of the nation's outstanding user facilities. BES principal investigators are recognized through the receipt of dozens of major prizes and awards from the scientific community.

The BES program has taken a leadership role in defining and addressing the 21st century challenges facing the physical and biological sciences – from understanding collective effects in materials to designing new materials atom by atom and, finally, to developing functional materials. This work underpins the nanoscale science, engineering, and technology initiative. In addition, BES will support construction of the Spallation Neutron Source and ongoing enhancements and maintenance activities at existing reactor and spallation neutron sources and synchrotron light sources.

The BES FY 2001 request supports the Climate Change Technology Initiative (CCTI) emphasizing fundamental research in sequestration science, science for efficient technologies, and fundamental science to advance low- and no-carbon energy sources. Examples include such diverse topics as: high-temperature materials for more efficient combustion; magnetic materials that reduce energy loss during use; semiconductor materials for solar-energy conversion; the foundations to enable evaluation of carbon dioxide sequestration in subsurface geologic formations; and the biological process of photosynthesis, which is central to global carbon cycling.

BES plays a central role in several of the SC priorities for FY 2001 described previously including the construction of the Spallation Neutron Source, enhanced Scientific Facility Utilization, and the National Nanotechnology Initiative. FY 2001 funding also is being requested in BES for fundamental research on microbial biochemistry. Microbes have dramatic impacts on energy production and conservation. The knowledge of the complex interactions that collectively characterize the life and function of these simplest of life forms will permit the control, modification, and use of microbes for both natural and industrial energy-related applications.

BES will also increase its investments in Robotics and Intelligent Machines for future applications important to DOE missions and to enable remote access to the SC user facilities.

The **Biological and Environmental Research** (BER) program has, for over 50 years, invested in advanced environmental and biomedical research to develop knowledge connected to energy. Fundamental research in genomics, structural biology, medical imaging, biomedical engineering, global climate change, and bioremediation at national laboratories, universities, and private institutions, BER develops the knowledge needed to identify, understand, and anticipate the long-term health and environmental consequences of energy production, development and use.

The scientific user facilities supported by BER provide unique capabilities for research in such key areas as structural biology and environmental science. Expanded funding for scientific facilities utilization will assure access to these facilities by scientists in universities, federal laboratories, and industry and will leverage both federally and privately sponsored research.

Construction of a new facility, the Laboratory for Comparative and Functional Genomics will be initiated at Oak Ridge National Laboratory. This facility will support high throughput determination of gene function in the mouse, a minimal model that is a key component of the Department's genome program.

In FY 2001, BER will continue to support basic research that contributes to interagency programs on the global impacts of and solutions for excess carbon in the environment - CCTI and the U.S. Global Change Research Program (US/GCRP).

The BER CCTI program is focused on carbon sequestration through enhancement of the natural terrestrial carbon cycle and sequestration of carbon in the oceans. The BER program complements carbon sequestration programs in BES and the DOE Office of Fossil Energy that focus primarily on other options for carbon sequestration.

FY 2001 will bring the first substantive research results from two new carbon sequestration sites that started collecting data at the end of FY 1999. Individual research projects at universities and national laboratories, started in FY 2000 and FY 2001, will also begin to yield results. The DNA sequences of four microorganisms that play prominent roles in the natural carbon cycle will have been determined. Structural biology studies will be conducted on the enzymes that regulate the processing of carbon in these four microbes to understand the molecular details of, and possibly to modify, these enzymes. Additional microbes with potential utility for enhanced carbon sequestration will also undergo DNA sequencing.

BER will initiate the Microbial Cell Project and expand its Biomedical Engineering Program as part of the Department's Life Sciences effort.

The **High Energy Physics** (HEP) program is directed at understanding the nature of matter and energy at the most fundamental level and the basic forces that govern all processes in nature. Fundamental research provides the foundation for our technology driven economy and advances the technically challenging missions of the Department of Energy.

The HEP FY 2001 request takes into consideration the recommendations of the High Energy Physics Advisory Panel's Gilman Report entitled "Planning for the Future of High-Energy Physics" (1998) through participation in the LHC project, increased support of university researchers, and optimum utilization of U.S. facilities.

The Fermilab 800 GeV fixed target program will complete data collection in FY 2000. Also in FY 2000, the Main Injector project was completed on schedule and within budget. The primary focus of the FY 2001 Fermilab program will be on Tevatron collider experiments that take advantage of the higher luminosity of the new Main Injector.

The SLAC B-factory was brought into full operation in FY 2000 on schedule and within budget. It has already recorded a world record peak luminosity of 2.7×10^{33} which is very close to the design luminosity of 3×10^{33} and an outstanding achievement for such a complex machine. In FY 2001 the B-factory will be operated for the BaBar experiment to collect data aimed at understanding matter-antimatter asymmetry.

The Alternating Gradient Synchrotron (AGS) at BNL was transferred from HEP to the Nuclear Physics Program in the 3rd Quarter of FY 1999 for use as part of the Relativistic Heavy Ion Collider (RHIC) facility. Limited operation of the AGS for HEP research is continuing in FY 2000 on an incremental cost basis. The high priority muon magnetic moment experiment took data in FY 2000 and will be completed during FY 2001. A follow-on experiment regarding the rare kaon will be supported in FY 2001.

The HEP program, in partnership with NSF, oversees U.S. participation in the Large Hadron Collider (LHC) at the European Laboratory for Particle Physics (CERN). HEP program funds were provided to support R&D, design and engineering work on the subsystems and components to be provided by the U.S. under the DOE-NSF agreement with CERN. The FY 2001 request for HEP includes $70 million for continued R&D, prototyping, setting up for production of accelerator components and ramping-up of production of detector subsystems. This work is part of the $450 million DOE contribution to the LHC effort negotiated with CERN.

Following the recommendations of the Gilman Report adopted by HEPAP, R&D will be continued on NLC with the goal of significantly reducing costs by applying such techniques as "design for manufacture". Fermilab has joined the R&D effort, which now involves four laboratories with SLAC as the lead laboratory and Fermilab, LBNL, and LLNL as partners.

The **Nuclear Physics** (NP) program provides primary support in the U.S. for fundamental research on the structure and interactions of atomic nuclei and the fundamental forces and particles of nature as manifested in nuclear matter. The NP program operates large and small research facilities located at DOE's national laboratories and research universities to provide microscopic probes of nuclear structures and forces.

The NP program works in close coordination with the Nuclear Physics program at the NSF and, jointly with NSF, charters the Nuclear Science Advisory Committee (NSAC) to provide advice on scientific opportunities and priorities. Construction of the Relativistic Heavy Ion Collider (RHIC) at BNL was completed in FY 1999 on schedule and within budget. Following initial operation and commissioning in FY 2000, RHIC will achieve full operation in FY 2001. Four detectors (STAR, PHENIX, BRAHMS and PHOBOS), involving over 950 researchers and students from 80 institutions and 19 nations, will allow a vigorous research program. The BNL Medium Energy Group will be re-directed in FY 2001 to concentrate on utilizing the new RHIC capabilities to investigate the origin of proton spin.

In FY 1999 the Isotope Separation On-Line Task Force, a subcommittee of NSAC, identified an optimal configuration for a next generation Rare Isotope Accelerator (RIA) facility. This facility was identified in the 1999 NSAC Long Range Plan for Nuclear Science as the highest priority for new construction. RIA R&D and preconceptual design activities continue in FY 2000 and FY 2001.

The U.S./Canadian Sudbury Neutrino Observatory (SNO) detector was completed in FY 1999. Data will be taken in FY 2000 and FY 2001 and initial measurements of solar neutrinos, relevant to the question of whether neutrinos have mass, are anticipated in FY 2001.

The Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Lab will increase beam energy to 6 GeV in FY 2001, enabling experiments to discern objects 50% smaller than the current operating energy. This will allow important new research that is not currently possible at CEBAF and much of the planned research program to be carried out twice as fast.

The BLAST detector at the MIT/Bates Linear Accelerator Center will be completed in FY 2001 and will initiate its research program, which will utilize high current continuous beams in the new South Hall Pulse Stretcher Ring.

The **Fusion Energy Sciences** (FES) program is the nation's primary sponsor of research in fusion science and plasma physics. It is a multi-purpose, research effort, producing valuable scientific knowledge and technological benefits in the near term and providing the science base for a fusion energy option in the long term. In FY 2001, FES will continue to make progress in: understanding the physics of plasmas; identifying and exploring innovative and cost-effective development paths to fusion energy; and exploring the science and technology of energy producing plasmas.

An integrated FES program plan will be completed during FY 2000. This plan will incorporate the findings and recommendations of the Secretary of Energy Advisory Board and National Research Council reviews as well as the technical understandings of the Fusion Energy Sciences Advisory Committee's assessment of the program and the 1999 Fusion Summer Study.

The FES program will continue to operate three significant user facilities: DIII-D at General Atomics, Alcator C-Mod at MIT, and NSTX at the Princeton Plasma Physics Laboratory (PPPL). Scientists from universities, industry, and national laboratories will continue world class experiments at DIII-D and Alcator C-Mod on advanced tokamak modes of operation. A team of scientists will conduct pioneering experiments on NSTX, a medium-scale spherical torus, which may lead to a more cost-effective development path to fusion energy. A DOE-NSF partnership in Basic Plasma Science and Engineering will continue, including a joint announcement to be issued in FY 2000 for new funding opportunities in FY 2001.

Operation of the Massachusetts Institute of Technology Levitated Dipole Experiment will begin in FY 2000, bringing the total number of exploratory level alternative concept experiments operating in the U.S. to 13. This important new investment is expected to pay dividends in the form of improved understanding of magnetic confinement concepts over the next decade.

The FES program also includes an increased effort on heavy ion accelerator physics aimed at a driver for inertial fusion. Successful completion of experiments using modular systems will lead to the design of an Integrated Research Experiment, a proof-of-principle inertial fusion energy facility.

The FES program continues to work toward improving the scientific and programmatic coordination between the magnetic and inertial elements of the program. Bilateral and multilateral science and technology research activities on major scientific facilities abroad will enable U.S. scientists to access plasma conditions not readily available on domestic facilities.

A Virtual Laboratory for Technology uses the internet to integrate all of the enabling technology R&D elements into a coordinated national program. Research will continue on low activation materials, high heat flux component systems, and magnetic, heating and fueling components.

The **Advanced Scientific Computing Research** (ASCR) program's primary mission is to discover, develop, and provide to researchers in various scientific disciplines the computational and networking tools that enable them to analyze, model, simulate, and predict complex phenomena important to the Department of Energy.

To accomplish this mission, the program fosters and supports fundamental research in advanced computing research – applied mathematics, computer science, and networking – and operates supercomputer, networking, and related facilities.

These have played a critical role in the evolution of high performance computing and networks.

The Mathematical, Information, and Computational Sciences (MICS) subprogram is responsible for carrying out the primary mission of the ASCR program. In all of the areas in which MICS supports research, the mission requirements far exceed the current state-of-the-art and the tools that the commercial marketplace can deliver. For this reason, the MICS subprogram is carefully managed to: integrate basic research; transform basic research results into software that can be transferred to scientists in other disciplines; and partner with users in scientific disciplines to validate the usefulness of the approach.

In FY 2001 the MICS subprogram will enhance its efforts to produce scientific computing, networking and collaboration tools needed by DOE researchers. These efforts will: increase access to multi-teraflop computers; establish a number of centers focused on the software challenges confronting terascale users; build partnerships between mathematicians, computer scientists, and scientists in other disciplines to produce advanced scientific software; tie together the physical and software services via common software framework building blocks ("middleware") to enable the success of the unique, data intensive, collaboratories of the future; and make significant contributions to the nation's Information Technology Research and Development effort.

MICS is changing the way it allocates resources at NERSC in the 21st century. The new allocation procedure proscribes that 60% of the resources will continue to be allocated directly by the SC program offices to research that they have peer reviewed. 40% of the resources will be allocated based on an independent peer review of proposals for high performance computing resources in a manner similar to the way other DOE user facilities allocate resources.
The FY 2001 request for the ASCR program also supports the Laboratory Technology Research subprogram, whose mission is to foster and support high-risk research in the natural sciences and engineering in partnership with the private sector leading to innovative applications relevant to the nation's energy sector.

The **Multiprogram Energy Laboratories - Facilities Support** (MELFS) program supports line items construction projects to replace and upgrade the general purpose infrastructure of the 5 SC multiprogram labs. The program also provides Payment in-lieu of Taxes to local communities around ANL and BNL; and, provides landlord support of the Oak Ridge Reservation and Operations Office.

The SC multiprogram labs are all over 50 years old and infrastructure investments are needed to ensure that the general purpose infrastructure supports the Department's research needs in a safe, environmentally sound, reliable, productive and cost-effective manner now and into the future. The FY 2001 budget will provide for 5 new utility related projects at LBNL, BNL and ORNL including water distribution systems, heating and ventilation systems, fire protection, electrical systems and surface and groundwater protection.

The **Science Program Direction** budget consists of three subprograms: Program Direction, Science Education, and Field Operations. Program Direction pays for the Federal staff and key support activities that provide the programmatic guidance within the Office of Science at headquarters. It also supports program-specific staff directly involved in executing SC programs at the Chicago, Oakland, and Oak Ridge Operations Offices. In FY 2001 there will be continued emphasis on integrated business management technology initiatives and supporting the ongoing efforts begun in FY 2000 related to succession planning and increasing diversity of the workforce. In addition, resources will be devoted to support the Department's Scientific and Technical Workforce Retention and Recruitment effort.

Scientific and Technical Workforce Retention and Recruitment focuses on building and sustaining a talented and diverse workforce of Research and Development (R&D) Technical Managers. During 1999, DOE conducted a systematic analysis of critical staffing needs within the context of R&D program missions, which identified current and projected staffing shortfalls, especially in scientific and technical disciplines. The Department will include innovative recruitment strategies, retention incentives, and comprehensive training and development programs for new and current employees, and succession planning. The FY 2001 program direction request for the Office of Science includes $2.0 million for this Scientific and Technical Workforce Retention and Recruitment effort. These funds will enable the Office of Science to recruit experienced scientists and related support staff in areas important to the Department's science mission, motivate and retain top-performing technical managers, and provide training in areas crucial for effective job performance.

The Science Education subprogram has as its mission to foster the next generation of scientists and engineers. A recent National Science Foundation (NSF) survey documents a five-year decrease in the number of science and engineering graduate students. Other studies indicate that the number of S&E graduates taking government positions is also sharply down. Science Education activities enable college and university students and faculty to take advantage of fellowship and research opportunities at the national laboratories and user facilities. Such initiatives are tailored to recruit and retain students interested in science and engineering. Science Education also sponsors the Energy Research Undergraduate Laboratory Fellowship Program, the Albert Einstein Distinguished Educator Fellowship Program and the National Science Bowl®. The DOE Institute of Biotechnology, Environmental Science, and Computing for Community Colleges is also sponsored within Science Education. This is the result of a successful pilot in 1999. All of these efforts are designed to ensure that the next generation of scientists and engineers accept careers in and meet the challenges of fundamental science, energy, the environment, and national security.

Field Operations funds the core management and administrative Federal staff and the related operational costs at three of the Department's multi-program Operations Offices that report to SC: Chicago, Oakland, and Oak Ridge. This account provides the resources necessary to support the scientific and technical work performed on behalf of Science and other DOE programs within the field/laboratory structure. These resources will support integrated business management systems aimed at providing coordinated, efficient and effective services and process improvements.

The 5% cut in FY 2000 funding for field operations combined with the reorganization of field management has had an impact on SC's ability to manage our programs. With the new organization, SC is confident in our ability to efficiently and effectively manage the field within requested funding.

The **Technical Information Management** (TIM) program maximizes the return on DOE's $7 billion annual R&D investment by collecting, preserving, and disseminating information resulting from these research programs. This information is recorded in three forms: journals, technical reports, and pre-prints. The TIM program has produced world-class web-based systems to provide full-text, electronic access to all three sources of information. The DOE Information Bridge (www.doe.gov/bridge) provides access to 70,000 technical reports. The newly launch PubScience (www.doe.gov/pubsci) provides electronic access to over 1,000 physical science journals – analogous to the capability PubMed provides in the life sciences.

FY 2001 accomplishments will include expanded coverage of science journals and a fully operational, searchable pre-print network. Also, the TIM program will continue its important role in obtaining foreign research information through two international information exchanges and, for the first time, will provide access to this information in electronic full-text. Finally, the program will provide enhanced protection and secure electronic access to a 50-year old repository of classified and sensitive R&D information.

Closing:

The reduction of FY 2000 funds for contractor travel is having a significant impact on our ability to conduct forefront research in the fundamental sciences. The advance of research is greatly aided by the exchange of ideas and the sharing of experiences. In many of the disciplines supported by the Office of Science, important exchanges take place at national and international scientific meetings and through interpersonal exchanges. Reductions in contractor travel have hampered these exchanges and have impacted SC's ability to recruit young scientists to the national laboratories.

James Decker

Director (Acting)

Office of Science

Table 1

OFFICE OF SCIENCE
FY 2001 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

	FY 1999 Conf. Approp.	FY 2000 Conf. Approp.	FY 2001 Pres. Request
Science			
Basic Energy Sciences	783,185	771,561	1,015,770
Advanced Scientific Computing Research	153,512	127,883	181,970
Biological and Environmental Research	425,890	432,886	445,260
Fusion Energy Sciences	217,248	244,686	247,270
High Energy Physics	680,716	697,743	714,730
Nuclear Physics	327,168	347,714	369,890
Energy Research Analyses	976	991	1,000
Multiprogram Energy Laboratories-Facilities Support	21,260	33,055	33,930
Science Program Direction	49,453	131,108	141,245
Small Business Innovation Research and Small Business Technology Transfer	81,461	-	-
Subtotal	2,740,869	2,787,627	3,151,065
General Reduction for Use of Prior Year Balances	(13,000)	-	-
Superconducting Super Collider	(7,600)	-	-
Total	2,720,269	2,787,627	3,151,065
Energy Supply R&D			
Technical Information Management	8,836	8,600	9,302
Small Business Innovation Research and Small Business Technology Transfer	4,874	-	-
General Reduction for Use of Prior Year Balances	(250)	-	-
Total	13,460	8,600	9,302

Table 2

OFFICE OF SCIENCE
FY 2001 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

	FY 1999 Conf. Approp.	FY 2000 Conf. Approp.	FY 2001 Pres. Request
Global Climate Change	111,608	119,901	122,347
Climate Change Technology Initiative	13,500	33,000	36,700
Science and Education Programs	4,500	4,500	6,500
Nanoscience Engineering and Technology	-	47,660	83,595
Robotics and Intelligent Machines	-	700	2,700
Microbial Cell Research	-	-	12,500
Bioengineering Research	-	1,700	6,700

Table 3

OFFICE OF SCIENCE
FY 2001 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

Major Site Funding	FY 1999 Conf. Approp.	FY 2000 Conf. Approp.	FY 2001 Pres. Request
AMES LABORATORY			
Advanced Scientific Computing Research	2,239	1,672	1,571
Basic Energy Sciences	18,838	16,990	16,165
Biological and Environmental Research	900	660	525
Total Laboratory	21,977	19,322	18,261
ARGONNE NATIONAL LABORATORY			
Advanced Scientific Computing Research	19,032	12,187	11,958
Basic Energy Sciences	144,752	140,005	160,726
Biological and Environmental Research	10,198	9,040	20,780
Fusion Energy Sciences	2,604	2,339	2,270
High Energy Physics	9,679	9,702	11,055
Multiprogram Energy Labs-Facilities Support	7,089	4,980	6,660
Nuclear Physics	17,039	16,304	16,965
Science Program Direction	797	200	900
Total Laboratory	211,190	194,757	231,314
BROOKHAVEN NATIONAL LABORATORY			
Advanced Scientific Computing Research	2,023	1,811	1,504
Basic Energy Sciences	79,425	75,441	75,769
Biological and Environmental Research	23,413	19,163	16,758
Energy Research Analyses	48	50	-
High Energy Physics	69,514	30,990	38,844
Multiprogram Energy Labs-Facilities Support	1,349	6,881	6,659
Nuclear Physics	117,305	132,463	145,783
Science Program Direction	398	250	600
Total Laboratory	293,475	267,049	285,917

Major Site Funding	FY 1999 Conf. Approp.	FY 2000 Conf. Approp.	FY 2001 Pres. Request
THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY			
Advanced Scientific Computing Research	151	50	200
Biological and Environmental Research	260	-	-
Nuclear Physics	71,673	72,730	74,715
Science Program Direction	-	-	150
Total Laboratory	72,084	72,780	75,065
FERMI NATIONAL ACCELERATOR LABORATORY			
Advanced Scientific Computing Research	213	60	200
Energy Research Analyses	-	-	60
High Energy Physics	296,713	286,253	282,730
Total Laboratory	296,926	286,313	282,990
IDAHO NATIONAL ENGINEERING LABORATORY			
Basic Energy Sciences	3,709	2,674	3,121
Biological and Environmental Research	2,084	1,761	1,489
Fusion Energy Sciences	1,804	1,623	1,701
Nuclear Physics	80	-	-
Total Laboratory	7,677	6,058	6,311
LAWRENCE BERKELEY NATIONAL LABORATORY			
Advanced Scientific Computing Research	57,969	53,865	64,457
Basic Energy Sciences	66,080	63,386	68,537
Biological and Environmental Research	39,163	43,581	40,532
Energy Research Analyses	165	30	75
Fusion Energy Sciences	4,971	7,877	7,655
High Energy Physics	26,706	33,627	37,786
Multiprogram Energy Labs-Facilities Support	4,854	6,133	2,113
Nuclear Physics	23,222	17,232	17,250
Science Program Direction	309	225	500
Total Laboratory	223,439	225,956	238,905

Major Site Funding	FY 1999 Conf. Approp.	FY 2000 Conf. Approp.	FY 2001 Pres. Request
LAWRENCE LIVERMORE NATIONAL LABORATORY			
Advanced Scientific Computing Research	3,620	3,210	3,160
Basic Energy Sciences	6,618	6,336	6,195
Biological and Environmental Research	41,127	40,110	38,875
Fusion Energy Sciences	11,696	13,063	12,716
High Energy Physics	1,496	1,230	850
Nuclear Physics	710	564	785
Total Laboratory	65,267	64,513	62,581
LOS ALAMOS NATIONAL LABORATORY			
Advanced Scientific Computing Research	15,206	11,873	10,560
Basic Energy Sciences	24,950	24,427	27,861
Biological and Environmental Research	22,362	19,280	17,971
Fusion Energy Sciences	4,365	6,094	5,960
High Energy Physics	870	860	800
Nuclear Physics	10,505	9,986	10,095
Total Laboratory	78,258	72,520	73,247
OAK RIDGE NATIONAL LABORATORY			
Advanced Scientific Computing Research	13,392	7,584	6,719
Basic Energy Sciences	221,267	207,551	372,644
Biological and Environmental Research	28,062	25,988	29,144
Energy Research Analyses	-	40	40
Fusion Energy Sciences	18,093	17,550	17,621
High Energy Physics	240	240	240
Multiprogram Energy Labs-Facilities Support	6,808	1,101	6,627
Nuclear Physics	16,094	15,173	16,120
Science Program Direction	439	320	800
Total Laboratory	304,395	275,547	449,955

Major Site Funding	FY 1999 Conf. Approp.	FY 2000 Conf. Approp.	FY 2001 Pres. Request
PACIFIC NORTHWEST NATIONAL LABORATORY			
Advanced Scientific Computing Research	4,312	2,602	2,210
Basic Energy Sciences	12,887	12,063	12,295
Biological and Environmental Research	79,879	64,339	65,312
Energy Research Analyses	250	250	300
Fusion Energy Sciences	1,415	1,385	1,385
High Energy Physics	10	-	-
Science Program Direction	572	275	750
Total Laboratory	99,325	80,914	82,252
NATIONAL RENEWABLE ENERGY LABORATORY			
Advanced Scientific Computing Research	127	-	-
Basic Energy Sciences	4,492	5,180	5,116
Total Laboratory	4,619	5,180	5,116
PRINCETON PLASMA PHYSICS LABORATORY			
Advanced Scientific Computing Research	121	45	200
Basic Energy Sciences	675	-	-
Fusion Energy Sciences	52,129	62,970	70,219
High Energy Physics	120	120	120
Science Program Direction	-	-	250
Total Laboratory	53,045	63,135	70,789
SANDIA NATIONAL LABORATORY			
Advanced Scientific Computing Research	5,651	4,798	4,705
Basic Energy Sciences	27,142	23,075	23,879
Biological and Environmental Research	3,537	1,490	3,091
Energy Research Analyses	-	50	75
Fusion Energy Sciences	4,120	3,338	3,232
Total Laboratory	40,450	32,751	34,982

Major Site Funding	FY 1999 Conf. Approp.	FY 2000 Conf. Approp.	FY 2001 Pres. Request
STANFORD LINEAR ACCELERATOR CENTER			
Advanced Scientific Computing Research	1,052	375	450
Basic Energy Sciences	26,475	23,042	31,592
Biological and Environmental Research	2,771	2,450	3,500
Fusion Energy Sciences	50	50	-
High Energy Physics	146,559	151,377	157,257
Science Program Direction	15	-	150
Total Laboratory	176,922	177,294	192,949

High Energy Physics

Program Mission

The High Energy Physics (HEP) program of the Department of Energy (DOE) has the lead responsibility for Federal support of high energy physics research and supports fundamental research activities under the mandate provided in Public Law 95-91 which established the Department. The High Energy Physics program is a key element in the Science and Technology component of the DOE Strategic Plan, supporting several of the strategies which make up that component. This program is also one of the identified elements in the Secretary's Performance Agreement with the President, and is an integral part of the Department's fundamental research mission. The program is directed at understanding the nature of matter and energy at the most fundamental level, and the basic forces which govern all processes in nature. Fundamental research provides the necessary foundation that ultimately enables the Nation to progress in its science and technology capabilities, to advance its industrial competitiveness, and to discover new and innovative approaches to our energy future.

The high quality of the research in this program is continuously evaluated through the use of merit based peer review and scientific advisory committees.

Program Goal

Provide new insights into the nature of energy and matter to better understand the natural world.

Program Objectives

- *To continue to support high quality research*—Support high quality university and laboratory based high energy physics research, both theoretical and experimental. Experimental research is primarily performed by university scientists using particle accelerators located at major laboratories in the U.S. and abroad.
- *To effectively operate the department's high energy physics accelerator facilities*—Provide optimal and cost effective operation for research of the Fermi National Accelerator Laboratory, and the Stanford Linear Accelerator Center. The Alternating Gradient Synchrotron (AGS) complex at the Brookhaven National Laboratory was transferred to the Nuclear Physics (NP) program during FY 1999. HEP use of the AGS will continue on an incremental cost basis.
- *To continue to provide world class research facilities*—Plan for and build new, state-of-the-art research facilities that allow researchers to advance the forefront of the science of high energy physics. Support essential improvements and upgrades at the major accelerator laboratories. Manage the commissioning of the Fermilab Main Injector project, the initial operation of the B-factory at SLAC and the continuation of the new experimental facility at Fermilab called Neutrinos at the Main Injector (NuMI).
- *To continue to provide the program's technological base*—Support long-range accelerator and detector R&D required to provide the advanced concepts and technologies that are critical to the long-range viability of high energy physics research.

- *To continue to pursue international collaboration on large high energy physics projects*—Using the management and control systems already put into place, work to successfully carry out the planned and agreed to collaboration with CERN on the Large Hadron Collider (LHC) project. Work to explore and pursue other opportunities for effective and beneficial international collaborative activities.

Performance Measures

Performance measures related to basic science activities are primarily qualitative rather than quantitative. The scientific excellence of the High Energy Physics program is continually reevaluated through the peer review process. Some specific performance measures are:

- Quality of scientific results and plans as indicated by expert advisory committees, recognition by the scientific community, and awards received by DOE-supported High Energy Physics researchers. The results of these reviews and other quality measures will be used to determine programmatic directions aimed at maintaining the world leadership position of the U.S. high energy physics program.
- Sustained achievement in advancing knowledge, as measured by the quality of the research based on results published in refereed scientific journals, and by the degree of invited participation at national and international conferences and workshops.
- Operation of research facilities in a manner that meets user requirements, as indicated by achieving performance specifications while protecting the safety of the workers and the environment, and by the level of endorsement by user organizations; operating facilities that are used for research at the forefront of science; and operating facilities reliably and according to planned schedules. In FY 2001, High Energy Physics will be operating the B-factory at SLAC, the Main Injector for the Tevatron at Fermilab, and using the AGS at BNL.
- Progress on achieving luminosity and operational efficiency for the B-factory at SLAC as measured by comparison with stated project goals.
- Progress on maintaining luminosity and operational efficiency for the Tevatron at Fermilab in its new mode of operation with the recently completed Main Injector.
- The upgrade of scientific facilities will be managed to keep them on schedule and within cost.
- Deliver on the scheduled U.S./DOE commitments to the international Large Hadron Collider project.
- Review at least 80 percent of the research projects by appropriate peers; continue to select research projects through a merit-based competitive process.
- Meet on time and within budget the scheduled U.S. DOE commitments to the international Large Hadron Collider project as reflected in the latest international agreement and corresponding plan.
- Make progress on the Neutrinos at the Main Injector project as measured by accomplishment of scheduled milestones as detailed in the benchmark plan.
- High Energy Physics plans and research will be recognized as outstanding by expert advisory committees such as the High Energy Physics Advisory Panel (HEPAP) and through other rigorous peer review. Additionally, the scientific results will be recognized through the awards received by its researchers and by the broader scientific community.

Significant Accomplishments and Program Shifts

- The long range planning study of the High Energy Physics program was prepared in 1998 by a Subpanel of the High Energy Physics Advisory Panel (HEPAP), (Gilman report). Their report is entitled "Planning for the Future of U.S. High-Energy Physics." The Subpanel's recommendations were considered carefully in preparing this budget.
- In FY 1999, the following performance goals were fully met:
  - Continue collaborative efforts with NASA on space science and exploration.
  - Deliver on the 1999 US/DOE commitments to the international LHC project.

Research and Technology

- In FY 1997, a test of a superconducting accelerator-style magnet fabricated at Lawrence Berkeley National Laboratory (LBNL) achieved a field strength of greater than 11 teslas in a new rectangular geometry with no quenches. This is a significant accomplishment in the effort to advance technology for future accelerators.

The following were accomplished in FY 1999:

- Measurement, by teams of university and laboratory scientists working at Fermilab, of the mass and production properties of the top quark was accomplished. This is the last, and by far the heaviest, of the fundamental building blocks of matter (quarks) whose existence was predicted by the Standard Model of elementary particles. The mass of the top quark is now measured more accurately than that of any of the other quarks. Further refinement of this result are continuing, and will improve even more with data from the upcoming run of the Tevatron with the newly upgraded Main Injector.
- The world's most precise measurement was made, by a team of university and laboratory scientists working at Fermilab, of the mass of the W boson. This result is now considerably more precise than the best measurement from LEP. It will improve even more with data from the upcoming run of the Tevatron with the newly upgraded Main Injector.
- The world's highest precision single measurement of the weak mixing angle, a fundamental parameter of the Standard Model, was made by a group of university and laboratory scientists working at SLAC with the Stanford Large Detector (SLD). The final result from the final data run has now been obtained.
- The observation was made, by the international CDF collaboration working at Fermilab, of the existence and properties of the B meson containing a charmed quark. This discovery completes the theoretically predicted family of B mesons.
- The observation of direct violation of CP symmetry in the decays of K mesons was made by a team of university and laboratory scientists working at Fermilab. More data is being analyzed to refine this result.
- The observation was made for the first time ever by the KTeV collaboration of the predicted decay of the kaon into a pair of pions and an electron-positron pair. Further refinement of this result was achieved.
- A major advance in theoretical physics was achieved when it was shown and verified that all of the known "string" theories are equivalent. This greatly reduces the number of possible theories which

describe all of the known forces including gravity. Further work toward delineating the underlying theory from which all string theories originate is continuing at a fast pace.

- A SLAC 30 GeV electron beam was directed down a 1.5 meter Lithium plasma creating a plasma wave that exhibited an accelerating gradient of greater than 0.5 GeV per meter, a record in this highly speculative program that may have a potential of approaching10's of GeV per meter accelerating gradient eventually.
- At the g-2 experiment at BNL, designed to study the magnetic properties of the muon, the most precise measurement of the anomalous magnetic moment has been obtained. Initial data collection has been completed and more data is being analyzed. Even more data should become available over the next two years. The experimenters are confident that they will achieve the world's best measurements of the anomalous magnetic moment and lifetime of the muon in both positive and negative charge states. If the final results agree with the standard model, this will place significant limits on new physics beyond the standard model.
- DOE is entering into an exciting and expanding partnership with NASA in the area of Particle Astrophysics. R&D for the Antimatter in Space (AMS) and Gamma Large Area Space Telescope (GLAST) experiments has been underway for some time. Preliminary consideration is being given to the SuperNova Acceleration Probe (SNAP) experiment. These experiments, and others that may be proposed, will provide important new information about cosmic rays and the rate of expansion of the universe which will in turn lead to a better understanding of dark matter, dark energy, and the original big bang.
- Evidence of neutrino mass and quantum mixing was obtained in a U.S.-Japanese experiment with the Super-Kamiokande experiment in Japan. Further data and refinement of these results was achieved. Long baseline neutrino beam experiments in Japan and at Fermilab are underway to verify these results.

High Energy Physics Facilities

- The final data collection with the Fermilab 800 GeV fixed-target program is being completed in FY 2000, and in FY 2001 the prime focus of the Fermilab program will turn to research using the Tevatron collider with the higher luminosity of the new Main Injector.
- The B-factory at SLAC was brought into full operation during FY 2000, and in FY 2001 will be operated for the BaBar experiment to collect data aimed at understanding matter-antimatter asymmetry as evidenced in the B-meson systems.
- The Alternating Gradient Synchrotron at BNL was transferred to the Nuclear Physics program for operation as the injector for the RHIC facility during the 3rd quarter of FY 1999. Beginning in FY 2000 AGS operation for High Energy Physics experiments is on an incremental cost basis. Limited operation of the AGS for HEP research is continuing on a non-interfering and incremental cost basis. The high priority muon magnetic moment experiment is taking data in FY 2000 and will be completed during FY 2001. A follow-on rare kaon experiment has been approved and will have a shake-down run in FY 2001.
- The Department is continuing research and development which will provide the basis for a reviewable technical design and cost estimate for a large electron-positron (antielectron) collider called the Next Linear Collider (NLC). The international high energy physics community has determined that such a machine is complementary to the Large Hadron Collider (LHC) now under

construction at the CERN Laboratory outside of Geneva, Switzerland, and essential if the issues of the physics beyond the Standard Model are to be effectively addressed. A formal endorsement was supplied in August 1999 in a statement on Linear Colliders issued by the International Committee of Future Accelerators (ICFA), sponsored by the Particles and Fields Commission of the International Union on Pure and Applied Physics (IUPAP):

> *"Scientific panels charged with studying future directions for particle physics in Europe, Japan, and the United States have concluded that there would be compelling and unique scientific opportunities at a linear electron-positron collider in the TeV energy range. Such a facility is a necessary complement to the LHC hadron collider now under construction at CERN. Experiment results over the last decade from the electron-positron colliders LEP and SLC combined with those from the Tevatron, a hadron collider, have led to this worldwide consensus.*
>
> *ICFA recommends continued vigorous pursuit of the accelerator research and development on a linear collider in the TeV energy range, with the goal of having designs complete with reliable cost estimates in a few years. We believe that an electron-positron collider optimized for the new physics should be built in a timely way with international participation."*

The technical basis for the advantages of electron-positron colliders is the precision associated with the fact that electrons and positrons are point particles (unlike the protons used in the LHC which are composites of three quarks), the more favorable secondary particle backgrounds, and the polarization (alignment of spin) of the electrons which adds a dimension of physics exploration not available with the LHC.

The R&D program is directed at a center-of-mass energy capability in the 500 to 1000 GeV (1 TeV) range, expandable to 1.5 TeV. This choice is based on the recommendations provided by the February 1998 report of the DOE HEPAP Subpanel on Planning for the Future of High Energy Physics which stated (Executive Summary):

> *"The Subpanel recommends that SLAC continue R&D with Japan's KEK toward a common design for an electron-positron linear collider with a luminosity of at least* $10^{34}\ cm^{-2}s^{-1}$ *and an initial capability of 1 TeV in the center of mass, extendible to 1.5 TeV. The Subpanel recommends that SLAC be authorized to produce a Conceptual Design Report for this machine in close collaboration with KEK."*
>
> *"This is not a recommendation to proceed with construction. A decision on whether to construct a linear collider should only follow the recommendation of a future subpanel convened after the CDR is complete. The decision will depend on what is known about the technology of linear colliders and other potential facilities, costs, international support, and advances in our physics understanding."*

The specific goals of the present NLC R&D program include developing new technologies that enable a higher performance, lower cost machine; carrying out systems engineering, value engineering, and risk analysis studies to identify additional R&D issues that could effect cost and performance and to down-select from available technologies; and using industrial firms to carry out R&D on key technologies, thus exploiting the special "design-for-manufacture" expertise available in industry and effecting technical transfer from the NLC R&D program to industry. In addition there is development of cost analysis and scheduling tools that can be used to guide the R&D

program by identifying cost driving technologies and that will be essential at such time as a Conceptual Design Report is authorized.

The NLC R&D activities to be supported by DOE are carried out by a national collaboration that includes SLAC as the principle laboratory, Fermilab as the major collaborator, and with significant contributions from Lawrence Berkeley National Laboratory and Lawrence Livermore National Laboratory. The R&D is also part of an international collaboration that includes the Japanese high energy physics center, KEK, through a SLAC-KEK inter-laboratory memorandum of understanding, and by less formal arrangements, with R&D groups at the German DESY Laboratory, CERN, and the Budker Institute in Russia.

The proposed DOE HEP funding is $17,000,000 in FY 1999, $17,400,000 in FY 2000, and $19,200,000 in FY 2001.

- Support for the Waste Management activities at LBNL is initiated in FY 2001 with a transfer of funds and responsibility from Environmental Management to HEP as the landlord for LBNL.

- The European Center for Nuclear Research (CERN) in Geneva, Switzerland has initiated the Large Hadron Collider (LHC) project. This will consist of a 7 on 7 TeV proton-proton colliding beams facility to be constructed in the existing Large Electron-Positron Collider (LEP) machine tunnel (LEP will be removed). The LHC will have an energy 7 times that of the Tevatron at Fermilab. Thus the LHC will open up substantial new frontiers for scientific discovery.

  Participation by the U.S. in the LHC program is extremely important to U.S. High Energy Physics program goals. The LHC will become the foremost high energy physics research facility in the world around the middle of the next decade. With the LHC at the next energy frontier, American scientific research at that frontier depends on participation in LHC. The High Energy Physics Advisory Panel (HEPAP) Subpanel on Vision for the Future of High-Energy Physics (Drell) strongly endorsed participation in the LHC, and this endorsement has been restated by HEPAP on several occasions.

  The physics goals of the LHC include a search for the origin of mass as represented by the “Higgs” particle, exploration in detail of the structure and interactions of the top quark, and the search for totally unanticipated new phenomena. Although LHC will have a lower energy than the Superconducting Super Collider (canceled in 1993), it has strong potential for answering the question of the origin of mass. The LHC energies are sufficient to test theoretical arguments for a totally new type of matter. In addition, history shows that major increases in the particle energy nearly always yield unexpected discoveries.

  DOE and NSF have entered into a joint agreement with CERN about contributions to the LHC accelerator and detectors as part of the U.S. participation in the LHC program to provide access for U.S. scientists to the next decade’s premier high energy physics facility. The resulting agreements were approved by CERN, the DOE and the NSF and were signed in December of 1997.

  Participation in the LHC project (accelerator and detectors) at CERN will primarily take the form of the U.S. accepting responsibility for designing and fabricating particular subsystems of the accelerator and of the two large detectors. Thus, much of the funding will go to U.S. laboratories, university groups, and industry for fabrication of subsystems and components which will become part of the LHC accelerator or detectors. A portion of the funds will be used to pay for purchases by

CERN of material needed for construction of the accelerator. As a result of the negotiations, CERN has agreed to make these purchases from U.S. vendors.

The agreement provides for a U.S. DOE contribution of $450,000,000 to the LHC accelerator and detectors over the period FY 1996 through FY 2004 (with approximately $81,000,000 being provided by the NSF). The DOE contribution is broken down as follows: detectors $250,000,000; accelerator $200,000,000 (including $90,000,000 for direct purchases by CERN from U.S. vendors and $110,000,000 for fabrication of components by U.S. laboratories).

The total cost of the LHC on a basis comparable to that used for U.S. projects is estimated at about $6,000,000,000. Thus the U.S. contribution represents less than 10 percent of the total. (The LHC cost estimates prepared by CERN, in general, do not include the cost of permanent laboratory staff and other laboratory resources used to construct the project.) Neither the proposed U.S. DOE $450,000,000 contribution nor the estimated total cost of $6,000,000,000 include support for the European and U.S. research physicists working on the LHC program.

The agreement negotiated with CERN provides for U.S. involvement in the management of the project through participation in key management committees (CERN Council, CERN Committee of Council, LHC Board, etc.). This will provide an effective base from which to monitor the progress of the project, and will help ensure that U.S. scientists have full access to the physics opportunities available at the LHC. The Office of Science has conducted a cost and schedule review of the entire LHC project and similar reviews of the several proposed U.S. funded components of the LHC. All of these reviews concluded the costs are properly estimated and that the schedule is feasible.

In addition to the proposed U.S. DOE $450,000,000 contribution and $81,000,000 NSF contribution to the LHC accelerator and detector hardware fabrication, U.S. participation in the LHC will involve a significant portion of the U.S. High Energy Physics community in the research program at the LHC. This physicist involvement has already begun. Over 500 U.S. scientists have joined the U.S.-ATLAS detector collaboration, the U.S.-CMS detector collaboration, or the U.S.-LHC accelerator consortium, and are hard at work helping to design the initial physics research program to be carried out at the LHC helping to specify the planned physics capabilities of the LHC accelerator and detectors, and helping to design and fabricate accelerator and detector components and subsystems.

Fabrication of LHC subsystems and components by U.S. participants began in FY 1998. Funding was provided in FY 1996 ($6,000,000) and FY 1997 ($15,000,000) for preliminary R&D, design and engineering work on the subsystems and components being proposed for inclusion in the agreement with CERN. This funding was essential in order to provide the cost and technical bases for the proposed U.S. responsibilities in LHC, and to be ready for rapid start to satisfy the anticipated timetable for the project. Funding in the amount of $35,000,000 was provided in FY 1998, $65,000,000 was provided in FY 1999, $70,000,000 was provided in FY 2000, and $70,000,000 will be provided in FY 2001 to support continuation of these R&D and design efforts, and the continuation of fabrication of those subsystems and components specified in the agreements with CERN.

The planned U.S. Funding for the LHC project is summarized below:

U.S. LHC Accelerator and Detector Funding

(dollars in thousands)

Fiscal Year	Department of Energy			National Science Foundation[a]
	Accelerator	Detector	Total	
1996[b]	2,000	4,000	6,000	0
1997[b]	6,670	8,330	15,000	0
1998[b]	14,000	21,000	35,000	0
1999	23,491	41,509	65,000	22,150
2000	33,206	36,794	70,000	15,900
2001	36,303	33,697	70,000	16,370
2002	31,200	38,800	70,000	16,860
2003	29,000	36,000	65,000	9,720
2004	24,130	29,870	54,000	0
Total	200,000[c]	250,000	450,000	81,000

Construction

- The Research Office Building project at SLAC was started in FY 2000. When completed in FY 2002, it will provide much needed office and laboratory space for the outside groups collaborating on the BaBar experiment.
- The Wilson Hall Safety Improvements Project at Fermilab is proceeding well and is on schedule for completion in FY 2001. The project is remediating structural deficiencies and addressing safety issues resulting from aging building components and systems.
- The Neutrinos at the Main Injector (NuMI) Project is proceeding on schedule. The project will provide a new neutrino beamline aimed at the Soudan Underground Laboratory in Soudan, Minnesota where the large MINOS detector will be installed to search for and study neutrino oscillations.

[a] The NSF funding has been approved by the National Science Board.

[b] The FY 1996 and FY 1997 LHC funding was for R&D, design and engineering work in support of the proposed U.S. participation in LHC. Beginning in FY 1998 funding was used for: fabrication of machine and detector hardware, supporting R&D, prototype development, and purchases by CERN from U.S. vendors.

[c] Includes $110,000,000 for LHC supporting R&D and accelerator components to be fabricated by U.S. laboratories and $90,000,000 for purchases by CERN from U.S. vendors.

Scientific Facilities Utilization

The High Energy Physics request includes $441,521,000 to maintain support of the Department's scientific user facilities. This investment will provide significant research time for several thousand scientists in universities, and other Federal laboratories. It will also leverage both Federally and privately sponsored research, consistent with the Administration's strategy for enhancing the U.S. National science investment. The proposed funding will support operations at the Department's two major high energy physics facilities: the Tevatron at Fermilab, and the B-factory at the Stanford Linear Accelerator Center (SLAC). The Alternating Gradient Synchrotron (AGS) at the Brookhaven National Laboratory (BNL), is now part of the Nuclear Physics (NP) funded Relativistic Heavy Ion Collider (RHIC) complex and is being operated for HEP purposes on a limited basis.

Funding of Contractor Security Clearances

In FY 1999, the Department divided the responsibility for obtaining and maintaining security clearances. The Office of Security Affairs, which was responsible for funding all Federal and contractor employee clearances, now pays only for clearances of Federal employees, both at headquarters and the field. Program organizations are now responsible for contractor clearances, using program funds. This change in policy enables program managers to make the decisions as to how many and what level clearances are necessary for effective program execution. In this way, it is hoped that any backlog of essential clearances which are impeding program success can be cleared up by those managers most directly involved. The Office of Science is budgeting $270,000 in FY 2000 and in FY 2001 for estimated contractor security clearances within this decision unit.

Workforce Development

The national laboratories, with significant High Energy Physics programs, provide a wide range of facilities and services for users, as well as maintaining their own scientific staffs which perform high-energy physics research in collaboration with outside users. Operating accelerators which provide beams for experiments is the primary service for users for Fermilab National Accelerator Laboratory, the Stanford Linear Accelerator Laboratory, and the Brookhaven National Laboratory. Other critical functions include providing technical staff and facilities for the design and fabrications of experiments, computing resources required to analyze the large data samples generated by experiments, research and development for future accelerators, and a host of services to support a large body of resident users, which includes graduate students, post-docs, and visiting faculty.

Scientific productivity is evaluated through peer review. The quality and importance of scientific results cannot be reduced to simple numerical measures of arbitrarily defined quantities. The Division of High Energy Physics conducts reviews of all aspects of the High Energy Physics program, including the programs and operations of the national laboratories. Experts in relevant areas participate in these reviews. The peer review process not only provides evaluations of the scientific productivity of various components of the High Energy Physics program, but also provides advice and suggestions for making improvements. Such guidance is critical in determining future programmatic directions so that the U.S. can maintain its place as a world leader in high-energy physics research. In FY 1999, 1,142 graduate students and post doc investigators were supported by HEP; 630 of those students and investigators were working at HEP user facilities.

Funding Profile

(dollars in thousands)

	FY 1999 Current Appropriation	FY 2000 Original Appropriation	FY 2000 Adjustments	FY 2000 Current Appropriation	FY 2001 Request
High Energy Physics					
Research and Technology	214,891	229,190	0	229,190	237,720
High Energy Physics Facilities	444,825	450,000	-10,147	439,853	444,610
Subtotal, High Energy Physics	659,716	679,190	-10,147	669,043	682,330
Construction	21,000	28,700	0	28,700	32,400
Subtotal, High Energy Physics	680,716	707,890	-10,147	697,743	714,730
Use of Prior Year Balances	-1,610[a]	0	0	0	0
General Reduction	0	-6,001	6,001	0	0
Contractor Travel	0	-1,771	1,771	0	0
Omnibus Rescission	0	-2,375	2,375	0	0
Total, High Energy Physics	679,106[b]	697,743	0	697,743	714,730[c]

Public Law Authorization:

Public Law 95-91, “Department of Energy Organization Act”

Public Law 103-62, “Government Performance Results Act of 1993”

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $13,972,000 which has been transferred to the SBIR program and $838,000 which has been transferred to the STTR program.

[c] Includes $5,500,000 for Waste Management activities at Lawrence Berkeley National Laboratory that was previously budgeted in FY 1999 and FY 2000 in the Environmental Management program.

Funding by Site

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	870	860	800	-60	-7.0%
Albuquerque Operations Office	0	13	0	-13	-100.0%
Total, Albuquerque Operations Office.........	870	873	800	-73	-8.4%
Chicago Operations Office					
Argonne National Laboratory	9,679	9,702	11,055	+1,353	+13.9%
Brookhaven National Laboratory	69,514	30,990	38,844	+7,854	+25.3%
Fermi National Accelerator Laboratory .	296,713	286,253	282,730	-3,523	-1.2%
Princeton Plasma Physics Laboratory ..	120	120	120	0	0.0%
Chicago Operations Office...................	82,721	87,042	78,783	-8,259	-9.5%
Total, Chicago Operations Office................	458,747	414,107	411,532	-2,575	-0.6%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	26,706	33,627	37,786	+4,159	+12.4%
Lawrence Livermore National Laboratory	1,496	1,230	850	-380	-30.9%
Stanford Linear Accelerator Center	146,559	151,377	157,257	+5,880	+3.9%
Oakland Operations Office...................	34,967	38,290	33,342	-4,948	-12.9%
Total, Oakland Operations Office...............	209,728	224,524	229,235	+4,711	+2.1%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education	189	80	150	+70	+87.5%
Oak Ridge National Laboratory	240	240	240	0	0.0%
Oak Ridge Operations Office	250	214	197	-17	-7.9%
Total, Oak Ridge Operations Office	679	534	587	+53	+9.9%
Richland Operations Office					
Pacific Northwest National Laboratory ..	10	0	0	0	0.0%
Washington Headquarters	10,682	57,705	72,576	+14,871	+25.8%
Subtotal, High Energy Physics..................	680,716	697,743	714,730	+16,987	+2.4%
Use of Prior Year Balances..................	-1,610[a]	0	0	0	0.0%
Total, High Energy Physics........................	679,106[b]	697,743	714,730[c]	+16,987	+2.4%

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $13,972,000 which has been transferred to the SBIR program and $838,000 which has been transferred to the STTR program.

[c] Includes $5,500,000 for Waste Management activities at Lawrence Berkeley National Laboratory that was previously budgeted in FY 1999 and FY 2000 in the Environmental Management program.

Site Description

Argonne National Laboratory

Argonne National Laboratory in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. High Energy Physics supports a program of physics research and technology R&D at ANL, using unique capabilities of the laboratory in the areas of accelerator R&D techniques and participation in the CDF and MINOS detector collaborations.

Brookhaven National Laboratory

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. High Energy Physics supports a program of physics research and technology R&D at BNL, using unique capabilities of the laboratory, including the Accelerator Test Facility and the capability for precision experimental measurement. High Energy Physics also makes limited use of the Alternating Gradient Synchrotron which is principally supported by the Nuclear Physics program.

Fermi National Accelerator Laboratory

Fermi National Accelerator Laboratory is a program-dedicated laboratory (High Energy Physics) located on a 6,800 acre site in Batavia, Illinois. Fermilab operates the Tevatron accelerator and colliding beam facility which consists of a four mile ring of superconducting magnets and is capable of accelerating protons and antiprotons to one TeV. Thus the Tevatron is the highest energy particle accelerator in the world, and has a unique capability for research at the energy frontier. Fermilab, together with SLAC, constitute the principal experimental facilities of the DOE High Energy Physics program.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located in Berkeley, California. The Lab is on a 200 acre site adjacent to the Berkeley campus of the University of California. High Energy Physics supports a program of physics research and technology R&D at LBNL, using unique capabilities of the laboratory primarily in the areas of participation in the BaBar collaboration, expertise in superconducting magnet R&D, world-forefront expertise in laser driven particle acceleration, and expertise in design of forefront electronic devices.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory is a Multiprogram Laboratory located on a 821 acre site in Livermore, California. High Energy Physics supports a program of physics research and technology R&D at LLNL, using unique capabilities of the laboratory primarily in the area of advanced accelerator R&D and participation in the B-factory project.

Los Alamos National Laboratory

Los Alamos National Laboratory is a Multiprogram Laboratory located on a 27,000 acre site in Los Alamos, New Mexico. High Energy Physics supports a program of physics research and technology R&D at LANL, using unique capabilities of the laboratory primarily in the area of theoretical studies, and computational techniques for accelerator design.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education is located on a 150 acre site in Oak Ridge, Tennessee. The High Energy Physics program supports a small effort at ORISE in the area of program planning and review.

Oak Ridge National Laboratory

Oak Ridge National Laboratory is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The High Energy Physics program supports a small research effort using unique capabilities of ORNL primarily in the area of particle beam shielding calculations.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The High Energy Physics program supports a small research effort using unique capabilities of PNNL in the area of low background experiments.

Princeton Plasma Physics Laboratory

Princeton Plasma Physics Laboratory is a program-dedicated laboratory (Fusion Energy Sciences) located on 72 acres in Princeton, New Jersey. The High Energy Physics program supports a small research effort using unique capabilities of PPPL in the area of advanced accelerator R&D.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California. SLAC operates for High Energy Physics the newly completed B-factory, the SLAC Linear Collider with the Stanford Large Detector, and a program of fixed target experiments. All of these facilities make use of the two mile long linear accelerator, or linac. SLAC, together with Fermilab, constitute the principal experimental facilities of the DOE High Energy Physics program.

All Other Sites

The High Energy Physics program supports about 230 research groups at 106 colleges and universities located in 36 states, Washington, D.C., and Puerto Rico. The strength and effectiveness of the university-based program is critically important to the success of the program as a whole. These university based components of the HEP program provides access to some of the best scientific talent in the nation.

The High Energy Physics program also funds research at a small number of non DOE laboratories and non-government laboratories and institutes.

Research and Technology

Mission Supporting Goals and Objectives

The High Energy Physics program has two major subprograms. The Research and Technology subprogram provides support for the scientists who perform the research which is the core of the program, and the technology R&D, which is essential to maintain the accelerator and detector facilities at the cutting edge required for a successful research program. The High Energy Physics Facilities subprogram, described later, provides the large facilities – accelerators, detectors, colliding beam devices – needed for the research program.

The Physics Research category in the Research and Technology subprogram provides support for university and laboratory based research groups conducting experimental and theoretical research in high energy physics. This research probes the nature of matter and energy at the most fundamental level, and the characteristics of the basic forces in nature. Experimental research activities include: planning, design, fabrication and installation of experiments; conduct of experiments; analysis and interpretation of data; and publication of results. Theoretical physics research provides the framework for interpreting and understanding observed phenomena and, through predictions and extrapolations based on current understanding, identifies key questions for future experimental explorations. This subprogram supports research groups at more than 100 major universities and at 9 DOE laboratories.

The High Energy Physics Technology category in the Research and Technology subprogram provides the specialized advanced technology R&D required to sustain and extend the technology base and provide operational support for the highly specialized accelerators, colliding beams facilities, and detector facilities which are essential to the overall high energy physics program goal of carrying out forefront research. The objectives of this category include: 1) carrying out R&D in support of existing accelerator and detector facilities aimed at maintaining and improving their performance parameters and cost effectiveness; 2) carrying out R&D support of planned and proposed projects to maximize their performance goals and cost effectiveness; 3) carrying out R&D to transfer new concepts and technologies into practical application in the High Energy Physics context; and 4) carrying out R&D to search for and develop new concepts and ideas that could lead to significant enhancements for research capabilities or to significant cost savings in the construction and operation of new facilities. This category supports work primarily at the DOE labs, but also at universities, other federal labs, and in industry.

Performance Measures

- Quality of scientific results and plans as indicated by expert advisory committees, recognition by the scientific community, and awards received by DOE-supported High Energy Physics researchers. The results of these reviews and other quality measures will be used to determine programmatic directions aimed at maintaining the world leadership position of the U.S. high energy physics program.

- Sustained achievement in advancing knowledge, as measured by the quality of the research based on results published in refereed scientific journals, and by the degree of invited participation at national and international conferences and workshops.
- Review at least 80 percent of the research projects by appropriate peers; continue to select research projects through a merit-based competitive process.

Funding Schedule

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Physics Research	149,207	158,368	156,170	-2,198	-1.4%
High Energy Physics Technology	65,684	70,822	74,331	+3,509	+5.0%
SBIR/STTR	0	0	7,219	+7,219	+100.0%
Total, Research and Technology	214,891	229,190	237,720	+8,530	+3.7%

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001

Physics Research

Physics Research			
Universities	98,556	107,508	105,640
Fermilab	10,658	7,957	7,837
SLAC	12,094	11,635	11,715
BNL	8,198	9,997	9,842
LBNL	11,305	11,126	10,956
ANL	5,712	5,645	5,565
Other Physics Research	2,684	4,500	4,615
Total, Physics Research	149,207	158,368	156,170

- **Universities—**The University Program consists of groups at 102 universities doing experiments (79 universities) and theory (75 universities). These university groups plan, build, execute, analyze and publish results of experiments, train graduate students and post-docs; and provide theoretical concepts, simulations and calculations of physical processes involved in high energy physics. These university based research activities are described in more detail below. The recent HEPAP Subpanel (Gilman), recommended that the level of funding for the university

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
based portion of the program be substantially increased over inflation over the next two year period. Following this recommendation, the overall funding for the university program has been provided with a modest increase above inflation. This modest increase is composed primarily of an increase of $5,500,000 in the capital equipment allocated to the university program in High Energy Physics Facilities offset by the $1,868,000 decrease in operating funds shown below. The combination results in a 3.4% increase.			
▸ **University Research at Fermilab**—Some 56 DOE-funded universities participate in large international collaborations doing experiments at Fermilab. These experiments involve the CDF and D-Zero collider detectors, and the KTEV, FOCUS, MINOS, DONUT, and HYPER-CP experiments using external beams of kaons, photons, neutrinos and hyperons. Other experiments are performed in the antiproton accumulator. The experiments study the production and interaction of quarks and gluons as a probe for new particles such as the Higgs, search for evidence for the possible mass of the neutrino and for the transition of neutrinos among the various types, search for possible sources for the asymmetry of matter over antimatter in the universe, and a number of other topics. These universities help to fabricate the detectors, plan and execute the experiments, analyze data and publish the results. The participation has been and is expected to remain about constant, as activity related to 800 GeV fixed target experiments diminishes and Tevatron, MINOS, and other new experiments related activities increases.	25,705	28,045	27,555
▸ **University Research at SLAC**—Some 27 DOE-funded universities participate in large international collaborations doing experiments at SLAC. The experiments involve the BaBar detector and other smaller detectors for fixed target experiments. These experiments are investigating fundamental constituents of matter such as the b quark. In particular, the BaBar detector is being used to study the nature of CP violation in the B meson system.			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
These universities help to build the detectors, plan and carry out experiments, analyze the data and publish the results. The participation has been and is expected to remain about constant, as SLD diminishes, BaBar flourishes, and work on a future large linear collider continues.	10,420	11,370	11,170
‣ **University Research at BNL**—Some 10 DOE-funded universities participate in collaborative experiments at BNL. These experiments involve fixed targets and kaon or pion beams, colliding beams of protons (RHIC-SPIN) or nuclei (PHOBOS) at RHIC, and an external storage ring measuring the muon anomalous magnetic moment to high precision.	3,145	3,430	3,370
‣ **University Research at Cornell**—Some 11 university High Energy Physics groups with DOE funding participate in the electron-positron colliding beam experiments at Cornell's CESR facility utilizing the collaboratively built CLEO detector studying various aspects of b meson interactions and decay. They help to plan, build, execute, analyze and publish the experiments.	5,220	5,700	5,600
‣ **University Research not at Accelerators**—Some 29 DOE-funded universities are involved in High Energy Physics experiments not utilizing accelerators. These experiments, which are primarily in the areas of astrophysics and cosmology, include MACRO (Italy), Super-Kamiokande (Japan), KamLAND (Japan), SNO (Canada), CHOOZ (France), SOUDAN (Minnesota), CDMS (Stanford), GRANITE (Mt. Hopkins, Arizona), Palo Verde (Arizona) and AMS (Space Station). These university based research groups build the detectors, plan, and execute the experiment, analyze the data and publish the results.	8,050	8,780	8,630
‣ **University Research at Foreign Labs**—Universities funded by the DOE are doing experiments with international collaborations using facilities at foreign accelerator labs. Some 45 universities are conducting experiments at CERN (Switzerland), 11 at DESY (Germany), 10 at KEK (Japan), 1 at IHEP (Russia), 1 at BINP (Russia), and 2 at Beijing (China). This research addresses a wide range of fundamental			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
questions such as the search for the Higgs boson which may be a key to understanding the source of mass. They help to fabricate the detectors and experimental apparatus, plan and execute the experiments, analyze the data and publish the results.	21,805	23,790	23,375
‣ **University Research in Theory**—Some 75 universities with DOE funding participate in research in theoretical high energy physics. This effort is expected to remain about constant. They provide theoretical ideas, concepts, calculations and simulations of physical processes in high energy physics..	21,600	23,565	23,155
‣ **Other University Funding ¾** Primarily includes funding held pending completion of peer review of proposals that have been received, and funds to respond to new and unexpected physics opportunities. The Outstanding Junior Investigator program, that is intended to identify and provide support for highly promising investigators at an early stage in their careers, will continue at a level of about $400,000....	2,611	2,828	2,785
Total, Universities	98,556	107,508	105,640
▪ **Fermilab**—In FY 2001, the experimental physics research groups at Fermilab will be focused mainly on the following activities: data-taking with the upgraded CDF and D-Zero collider detector facilities, analysis of data taken in the 800 GeV fixed-target program, construction of the MINOS detector, construction of the CMS detector for the LHC. The theoretical particle physics and astrophysics groups will be working on a variety of theoretical topics.	10,658	7,957	7,837
▪ **SLAC**—The experimental physics research groups at SLAC will concentrate their efforts in FY 2001 on data-taking and analysis of data from the BaBar detector operating with the PEP-II accelerator facility, as well as completing the analysis of the data from the operation of the SLD detector. Fabrication of the Gamma Large Area Space Telescope (GLAST) will be a significant effort in FY 2001 in preparation for the launch projected to be in FY 2005. GLAST will study the very high energy cosmic rays reaching the earth before they have interacted in the			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
atmosphere. Some physics research will also be done by fixed target experiments. The theoretical physics group will continue to emphasize topics related to BaBar and the other SLAC experimental physics programs as well as tests of the Standard Model and Quantum chromodynamics (QCD).	12,094	11,635	11,715
▪ **BNL**—In FY 2001, the BNL experimental physics research groups will be primarily working on the D-Zero experiment, which will be taking data at Fermilab, and contributing to the fabrication of the ATLAS detector for the LHC. Data collection for the precision measurement of the anomalous magnetic moment of the muon will be completed. An upgraded rare kaon decay experiment at the AGS facility, will begin operation. The theoretical physics group will be working on a number of topics.	8,198	9,997	9,842
▪ **LBNL¾** In FY 2001, LBNL researchers will be focused on a number of research activities, including: data-taking with the CDF collider detector at Fermilab; data-taking with the BaBar detector at the PEP-II storage ring at SLAC; data-analysis on the HYPER-CP experiment will be underway; and fabrication of the ATLAS detector, primarily the silicon tracking system, for the LHC. The researchers will also be working on supernova measurements to establish values of cosmological parameters. Funding is included for the Particle Data Group at LBNL, which continues as an international clearinghouse for particle physics information.	11,305	11,126	10,956
▪ **ANL¾** The experimental high energy physics group will continue collaborating in research on the CDF at Fermilab, and ZEUS at the DESY/HERA facility in Hamburg, Germany. They also will be working on the fabrication of two major new detector facilities: the ATLAS detector for future use at CERN's LHC facility, and the MINOS detector at the Soudan site in Minnesota. The MINOS detector is part of the NuMI project and will use a neutrino beam from Fermilab. The theoretical physics group will continue their research in formal theory, collider phenomenology, and lattice gauge calculations	5,712	5,645	5,565

	FY 1999	FY 2000	FY 2001
▪ **Other Physics Research¾** LLNL is involved in the BaBar detector, in the MINOS project, as well as non-accelerator experiments. ORNL is carrying out accelerator and beamline shielding studies. LANL is involved in theoretical studies and certain non-accelerator experiments. Includes funds for research activities that have not yet completed their peer review. Funding at $1,800,000 is planned for an expanded R&D effort on the SNAP experiment to clarify the design, feasibility and scientific capability of the proposed instrument to explore dark matter, dark energy and the expanding universe by measuring the velocity of distant supernovae. This category also includes funding of conferences, studies, and workshops	2,684	4,500	4,615
Total, Physics Research	149,207	158,368	156,170

(dollars in thousands)

High Energy Physics Technology

High Energy Physics Technology			
Fermilab	15,900	14,430	15,370
SLAC	19,520	19,595	23,115
BNL	6,290	6,255	5,215
LBNL	10,247	10,518	10,328
ANL	2,150	2,160	2,135
Universities	9,049	11,595	11,965
Other Technology R&D	2,528	6,269	6,203
Total, High Energy Physics Technology	65,684	70,822	74,331

- **Fermilab**
  - Accelerator R&D—Activities in FY 2001 include design of an improved proton source; design of an electron cooling system to improve the quality of an antiproton beam processed through the Recycler ring; R&D in support of the NuMI project; engineering R&D on and construction of quadrupole magnets for the LHC interaction regions; and R&D to lay the technology foundations, long term, for possible future

	(dollars in thousands)	
FY 1999	FY 2000	FY 2001

accelerators and experiments. The latter includes continuation of R&D on the NLC begun formally in the first quarter of FY 2000 by a memorandum of understanding between SLAC and Fermilab. Fermilab has assumed the principle R&D responsibility for the two main linac beam lines, including accelerating structures, supports, and instrumentation and control. A major SLAC and Fermilab collaborative R&D activity is application of the Fermilab developed permanent magnet technology throughout the entire NLC beam optics chain. Fermilab is also responsible for applying their expertise in conventional civil construction to issues that could significantly reduce the NLC construction cost. There will also be an expanded accelerator physics effort, in collaboration with SLAC, to more fully understand all aspects of the beam optics and beam transport for the NLC from the electron and positron sources to the electron-positron collision point. Longer range R&D addresses the feasibility and design issues for muon colliders/neutrino sources. A critical test issue is the demonstration of the feasibility of ionization cooling. The muon cooling experiment, for which Fermilab is lead laboratory and LBNL a major collaborator, is part of a national Muon Collider/Neutrino Source Collaboration (including ANL, BNL, Fermilab, LBNL and a number of universities) that is also addressing the second critical issue (at BNL) of an intense Muon target/source and extensive accelerator physics and accelerator and storage ring systems studies. Fermilab is also engaged in an advanced superconducting magnet and materials program (principally niobium tin) to develop magnetic optical elements for use in a muon collider/neutrino source and, in the very far term, a possible 100 TeV proton collider. The general Accelerator R&D activities are increased by about $1,530,000 reflecting the need to support the initial operation of the Tevatron with the new Main Injector/Recycler and the two upgraded detectors, and the need for a more significant effort, as outlined above, to look at long term facility options for Fermilab and for the national program. NLC R&D

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
will decrease by $500,000 to $1,200,000 in FY 2001. The muon collider R&D activities will remain constant in FY 2001.	8,540	8,430	9,460
‣ Experimental Facilities R&D: Activities in FY 2001 include: R&D on pixel silicon detectors and related R&D for a possible dedicated collider detector for studying B meson interactions; R&D on photon veto systems for an experiment searching for rare decays of kaons; R&D on radiation-hard materials such as diamond and silicon carbide to replace silicon micro strip detectors at high collision rates; R&D on specialized electronics for high event rates in numerous, high-density data channels; and developing parallel computing configurations, high speed networks, and high-capacity data storage systems for high data rates.	7,360	6,000	5,910
Total, Fermilab	15,900	14,430	15,370

▪ **SLAC**

‣ Accelerator R&D—Activities in FY 2001 will focus on R&D issues central to the design of the Next Linear Collider (NLC), an electron-positron colliding beam facility to operate in the 500 GeV to 1 TeV center-of-mass energy regime upgradable to 1.5 TeV. The R&D activity at SLAC will focus on design and supporting engineering R&D on the electron and positron sources, damping rings, and connecting beam transport systems. Much of this work is done in collaboration with the Japanese laboratory for HEP, KEK. Technology development for the 11.4 Ghz high powered microwave sources that generate the power to accelerate electrons and positrons will continue with the goal of proving new, more cost effective technical approaches. Some of this R&D will be carried out through contracts placed with industry, exploiting the special “design for manufacture” expertise of industry and accomplishing technology transfer from SLAC to industry. Systems engineering, value engineering and risk analysis studies will be carried out to identify R&D opportunities to lower cost, exploit new technologies, and improve performance. There will be a major collaboration

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
activity with Fermilab to incorporate permanent magnet technology developed for the Fermilab Recycler into the NLC design. Expanded accelerator physics studies will explore the limits of machine performance, look for optimized beam optics and accelerating structure improvements. Some of this work is in collaboration with Fermilab, LBNL and LLNL. An important component of the FY 2001 SLAC program will be accelerator R&D in support of operation of the B-factory. Particular attention will be paid to finding ways to improve the collision luminosity from the design value of $3x10^{33}cm^{-2}s^{-1}$ to greater than $10^{34}cm^{-2}s^{-1}$. A program of general R&D into very advanced collider concepts will continue and will coordinate with the program in advanced accelerator physics that is exploring the potential of lasers, plasmas, and ultra high frequency microwave systems to accelerate charged particles at ultra high gradients. The advanced accelerator R&D will be given slightly increased priority relative to FY 2000. The NLC R&D will be funded at $16,500,000 in FY 2001. (An additional $500,000 is provided to LLNL in this category and $1,000,000 in capital equipment funding for NLC R&D needs is provided under High Energy Physics Facilities subprogram at SLAC).	17,620	17,500	22,050
‣ Experimental Facilities R&D—In FY 2001, the focus will be on instrumentation for physics studies in the center of mass collision energy range of 10 GeV to 5,000 GeV. This will include work to support and improve performance of BaBar, the newly operating B-factory detector, and a modest program of R&D, on developing preliminary designs for a detector to operate with a possible new electron-positron linear collider operating at the TeV center of mass energy scale	1,900	2,095	1,065
Total, SLAC	19,520	19,595	23,115

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
▪ **BNL**			
‣ Accelerator R&D—Activities in FY 2001 will include, R&D on new methods of particle acceleration such as laser acceleration and Inverse Free Electron Laser (IFEL) accelerators, primarily using the excellent capabilities of the BNL Accelerator Test Facility. BNL also has a major involvement in muon collider R&D, primarily in the area of the muon production target and collection systems. This target/capture R&D is critical for demonstrating the feasibility of a muon collider. In the BNL superconductor test facility the characterization of new high critical temperature superconductors as well as their special requirements for high field magnet fabrication should be better understood. R&D in support of AGS operation will continue at a low level, as needed, in relation to the HEP supported operation of the AGS.	5,215	5,180	4,155
‣ Experimental Facilities R&D—In FY 2001, semiconductor drift photo diodes for detection of photons of energies as low as 50 eV will be designed and produced. Development of radiation hardened monolithic electronics for a number of experiments will continue. Development of lead-tungstate crystals with improved light output will continue. Testing of the modules that constitute the ATLAS barrel calorimeters will begin..	1,075	1,075	1,060
Total, BNL..	6,290	6,255	5,215

▪ **LBNL**

‣ Accelerator R&D—LBNL is a major contributor to accelerator and superconducting magnet R&D for advanced accelerator concepts, including the muon collider and the next linear collider. Development of these concepts is needed to advance the energy and luminosity frontiers to better understand the structure of matter. In FY 2001, preparations for muon cooling experiments, needed to confirm the practicality of a muon collider, will begin at Fermilab, using components developed at LBNL. The high-gradient,

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
all-optical, laser-plasma wakefield accelerator at LBNL will begin accelerating electron bunches........	7,577	7,858	7,708
‣ Experimental Facilities R&D—LBNL has an industry forefront capability for designing and producing custom state-of-the-art electronics, such as silicon vertex detectors, integrated circuit (IC) systems, and other components for high-energy particle detectors such as BaBar at the B-factory and the upgrades to CDF and D–Zero for the next, higher luminosity, runs at Fermilab. LBNL is also involved in developing computer programs for experimental data taking and analysis. In FY 2001, work will continue on large area charge-coupled devices and high-resolution imaging systems, plus the production and testing of IC systems...	2,670	2,660	2,620
Total, LBNL..	10,247	10,518	10,328
▪ **ANL**			
‣ Accelerator R&D—R&D will continue on the acceleration of electrons using structures with plasmas or structures made of dielectric materials called wakefield accelerators. Researchers have achieved predicted accelerating gradients at encouraging levels using this new technique. Results are expected in obtaining high accelerating gradients with greatly enhanced beam stability using dielectric structures, and planning is underway for an upgraded experimental capability to generate much higher accelerator gradients using plasmas in structures driven by intense bunches of electrons. Related theoretical work will also continue.	1,230	1,240	1,225
‣ Experimental Facilities R&D—In FY 2001 work will be underway on the MINOS detector, the ATLAS detector for the LHC, and a possible upgrade of the ZEUS detector at DESY.	920	920	910
Total, ANL..	2,150	2,160	2,135

▪ **Universities¾** The funding will provide for a program of high priority technology R&D at about 35 universities relevant to the development of particle accelerators. The R&D is aimed at breakthrough technologies;

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
superconductors for high-field magnets; laser and collective-effect accelerator techniques; novel, high-power radio frequency generators; muon colliders; theoretical studies in particle beam physics, including the non-linear dynamics of particle beams; and at lowering the cost and improving the performance of future experiments and facilities..	9,049	11,595	11,965
▪ **Other Technology R&D**—The funding will provide for a program of high priority technology R&D at a number of other federal laboratories and industrial sites relevant to the development of particle accelerators. The R&D is aimed at breakthrough technologies; superconductors for high-field magnets; laser and collective-effect accelerator techniques; novel, high-power radio frequency generators; theoretical studies in particle beam physics, including the non-linear dynamics of particle beams; and at lowering the cost and improving the performance of future experiments and facilities. Also includes the portion of the funding for R&D on future facility concepts that has not yet been allocated pending program office discussions and peer reviews that are underway.	2,528	6,269	6,203
Total, High Energy Physics Technology...............................	65,684	70,822	74,331
▪ **SBIR/STTR**— Includes $6,370,000 for SBIR, and $849,000 for STTR in FY 2001. Additional funding for the SBIR program is contained in the High Energy Physics Facilities subprogram..	0	0	7,219
Total, Research and Technology...	214,891	229,190	237,720

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Physics Research	
‣ Operating expenses for the University Physics Research program decrease $1,868,000. This is more than offset by the $5,500,000 increase in capital equipment allocated for universities under the High Energy Physics Facilities subprogram.	-1,868
‣ At Fermilab, a decrease of $120,000 in research activities.	-120
‣ At SLAC, an increase of $80,000 related to the increased level of activity resulting from initial operation of the B-factory.	+80
‣ Research decreases at BNL (-$155,000), LBNL (-$170,000), and ANL (-$80,000).	-405
‣ An increase in the funding is unallocated pending the completion of peer reviews and programmatic consideration.	+115
Total, Physics Research	-2,198
High Energy Physics Technology	
‣ At Fermilab, an increase in the general Accelerator R&D of $1,530,000 to support work needed to fully integrate and utilize the capability provided by the new Main Injector; offset by decreases of $500,000 in next linear collider R&D and of $90,000 in Experimental Facilities R&D. Muon Collider R&D is held constant	+940
‣ At SLAC, an increase in general Accelerator R&D of $2,250,000 to support work needed to increase the luminosity of the B-factory. It is expected that the luminosity can be increased by a factor of three above the design value. There is also an increase in next linear collider R&D of $2,300,000 to allow this work to proceed on the planned schedule. These increases are partially offset by a decrease in Experimental Facilities R&D of $1,030,000 resulting from the completion of the BaBar detector.	+3,520
‣ At BNL, a decrease in general Accelerator R&D of $1,025,000 reflecting partial completion of a program to enhance the R&D capabilities of the lab, and other reductions in Accelerator R&D and Experimental Facilities R&D.	-1,040
‣ Modest decreases at LBNL ($190,000) and ANL ($25,000).	-215
‣ The University Technology R&D program increases $370,000. This provides an increase of about 3% for the university based Technology R&D program.	+370
‣ In Other Technology R&D, there is a small decrease in other activities.	-66
Total, High Energy Physics Technology	+3,509

	FY 2001 vs. FY 2000 ($000)
▪ SBIR/STTR	
‣ An increase of $7,219,000 in the SBIR and STTR allocation. In FY 2000, the SBIR/STTR allocations were all in the High Energy Physics Facilities subprogram.	+7,219
Total Funding Change, Research and Technology	+8,530

The following table summarizes the above changes for R&D on possible future HEP facilities:

	(dollars in millions)		
	FY 1999	FY 2000	FY 2001
Next Linear Collider	17.0	17.4	19.2
Muon-Muon Collider	5.5	8.7	8.7

High Energy Physics Facilities

Mission Supporting Goals and Objectives

The High Energy Physics Facilities subprogram includes the provision and operation of the large accelerator and detector facilities, the essential tools that enable scientists in university and laboratory based research groups to perform experimental research in high energy physics. This subprogram includes funding for the operation and maintenance of the national laboratory research facilities including accelerators, colliders, secondary beam lines, detector facilities for experiments, experimental areas, computing, and computing networking facilities. It includes the costs of detector and accelerator components, personnel, electric power, expendable supplies, replacement parts and subsystems, inventories and waste management activities at Fermilab and SLAC and at LBNL beginning in FY 2001. General Plant Projects (GPP) funding is provided for minor new construction, other capital alterations and additions and for buildings and utility systems. Landlord General Purpose Equipment (GPE), and GPP funding for Brookhaven National Laboratory in FY 1999 and for Lawrence Berkeley National Laboratory in FY 2000 and FY 2001; Fermi National Accelerator Laboratory and Stanford Linear Accelerator Center are also included. Accelerator Improvement Project (AIP) funding support for additions and modifications to accelerator facilities that are supported by the High Energy Physics research program is also included.

The principal objective of the High Energy Physics Facilities subprogram is to maximize the quantity and quality of data collected for approved experiments being conducted at the High Energy Physics facilities. The ultimate measure for success in the High Energy Physics Facilities subprogram is whether the research scientists have data of sufficient quantity and quality to do their planned measurements or to discover new phenomena. The quality of the data is dependent on the accelerator and detector capabilities, and on the degree to which those capabilities are achieved during a particular operating period. The quantity of the data relates primarily to the beam intensity, the length of the operating periods, and the operational availability of the accelerator and detector facilities.

Performance Measures

- Progress on achieving luminosity and operational efficiency for the B-factory at SLAC as measured by comparison with stated project goals.
- Progress on achieving luminosity and operational efficiency for the Tevatron at Fermilab in its new mode of operation with the recently completed Main Injector.
- The upgrade of scientific facilities will be managed to keep them on schedule and within cost.
- In FY 2001, High Energy Physics will be operating the B-factory at SLAC, the Main Injector for the Tevatron at Fermilab, and the AGS at BNL, and will deliver on the scheduled U.S./DOE commitments to the international Large Hadron Collider project.
- Meet on time and within budget the scheduled U.S. DOE commitments to the international Large Hadron Collider project as reflected in the latest international agreement and corresponding plan.

Planned Accelerator Operations

	(in weeks)		
	FY 1999	FY 2000	FY 2001
Fermilab	38	29	22
SLAC	42	39	36
BNL	14	15	17

Funding Schedule

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Fermi National Accelerator Lab	209,937	212,936	207,031	-5,905	-2.8%
Stanford Linear Accelerator Center	112,330	115,447	114,527	-920	-0.8%
Brookhaven National Laboratory	42,375	4,909	7,519	+2,610	+53.2%
Other Facility Support	10,273	16,982	27,338	+10,356	+61.0%
Large Hadron Collider	65,000	70,000	70,000	0	0.0%
Waste Management	4,910	4,910	10,410	+5,500	+112.0%
SBIR/STTR	0[a]	14,669	7,785	-6,884	-46.9%
Total, High Energy Physics Facilities	444,825	439,853	444,610	+4,757	+1.1%

Detailed Program Justification

(dollars in thousands)		
FY 1999	FY 2000	FY 2001

Fermilab

Provides support for operation, maintenance, improvement, and enhancement of the Tevatron accelerator and detector complex. This complex includes the Tevatron, that can operate in a collider mode with protons and anti-protons, or in a fixed target mode with protons only; the new Main Injector that will be completed and commissioned in FY 1999; the Booster; the Linac; and the Anti-proton Source and Accumulator. The Tevatron collider and the 800 GeV fixed target modes are mutually exclusive; however, a fixed target program at 120 GeV using the new Main Injector is possible in parallel with Tevatron collider operation. This complex also includes the two large colliding beams

[a] Excludes $13,972,000 which has been transferred to the SBIR program and $838,000 which has been transferred to the STTR program.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Detectors – CDF and D-Zero – and a number of fixed target experiments in the external beams areas.			
▪ **Operations**—Operation at Fermilab will include operation of the Tevatron in collider mode for about 22 weeks. This will be a major physics run with the higher intensity available from the new Main Injector and with the newly upgraded D-Zero and CDF detectors....................	167,129	175,507	172,773

Tevatron Operation

	(in weeks)		
	FY 1999	FY 2000	FY 2001
Fixed Target	22	6	0
Collider...	0	15	22
Commissioning	16	8	0
Total, Tevatron Operation...	38	29	22

▪ **Support and Infrastructure**— Capital equipment funding for the CDF and D-Zero Upgrade projects is significantly reduced (to $500,000 each) reflecting the planned completion of these two projects in FY 2001. Capital equipment for the MINOS detector is increased to $7,000,000. AIP is funded at $4,300,000 and GPP is funded at $4,800,000...	42,808	37,429	34,258
Total, Fermilab	209,937	212,936	207,031

SLAC

Provides for the operation, maintenance, improvement and enhancement of the accelerator and detector complex on the SLAC site. The accelerators include the electron linac, the NLC Test Accelerator and the B-factory completed in FY 1999. The detector facilities include BaBar, the detector for the B-factory, the End Station A experimental set-ups, and the Final Focus Test Beam. Also provides for maintenance of the laboratory physical plant.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
▪ **Operations**—Operations at SLAC in FY 2001 will concentrate heavily on about 36 weeks of strong utilization of the newly completed asymmetric B-factory colliding beam storage rings to maximize the data collected by the BaBar detector facility. This will be supplemented by a modest (8 weeks) fixed target research program in End Station A. The linac will serve as the injector of positrons and electrons to the B-factory storage rings during this time. This will be the priority research program at SLAC in FY 2001	92,795	95,147	95,447

SLAC Operation

	(in weeks)		
	FY 1999	FY 2000	FY 2001
Fixed Target	10	15[a]	8[k]
B-factory Commissioning	16	0	0
B-factory Operation	16	39	36
Total, SLAC Operation	42	39	36

	FY 1999	FY 2000	FY 2001
▪ **Support and Infrastructure**—Includes funding for capital equipment, AIP and GPP needs. Capital equipment funding for GLAST, a MIE with a preliminary TEC of $28,000,000, is included at $3,300,000. Additional capital equipment funding for GLAST in the amount of $1,300,000 is included in the Other Facility Support activity detailed later. Capital equipment for NLC R&D is included at $1,000,000.	19,535	20,300	19,080
Total, SLAC	112,330	115,447	114,527

BNL

Provides support for the HEP related operation, maintenance, improvement, and enhancement of the AGS complex at BNL and its complement of experimental set ups. The AGS was transferred to the Nuclear Physics program during the 3rd

[a] Fixed Target operation in parallel with B-factory operation.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
quarter of FY 1999 to be supported and operated as part of the RHIC facility. In FY 2000 and beyond operation of the AGS for the HEP program is on an incremental cost basis.			
▪ **Operations**—Operation activities covered under this budget category include the incremental cost of running the AGS complex for HEP. Operation for High Energy Physics in FY 2001 will be for about 17 weeks to complete the muon magnetic moment experiment and for initial operation of the upgraded rare kaon decay experiment. The large decrease from FY 1999 to FY 2000 reflects the transfer of the AGS from HEP to NP	33,938	3,490	5,920

AGS Operation

	(in weeks)		
	FY 1999	FY 2000	FY 2001
AGS Operation for HEP	14	15	17

▪ **Support and Infrastructure**—Includes capital equipment funding for the BNL HEP program. Included in FY 1999 only, landlord GPP and GPE funding.	8,437	1,419	1,599
Total, BNL	42,375	4,909	7,519

Other Facility Support

- Includes $5,000,000 for the establishment of an enhanced capability for large scale computer modeling and simulation. The initial application will be to detail orbit calculations in accelerator magnet rings, and in the large scale numerical calculations of fundamental interactions such as those in quark-gluon collisions.

  Includes $1,950,000 for General Purpose Equipment and $3,500,000 for General Plant Projects at LBNL for landlord related activities.

  Includes capital equipment funding at ANL, LBNL, and some smaller DOE labs. Includes funding for a number of small activities including computer networking. Includes $5,500,000 in capital equipment funding for the

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
University physics research program. These funds will be used primarily for the non-accelerator projects summarized below.	10,273	16,982	27,338

- The Cryogenic Dark Matter Search (CDMS) detector will use cryogenic techniques to search for weakly interacting massive particles (WIMPS). WIMPS are proposed as a possible explanation for the "missing" mass in the universe. CDMS is being done by a collaboration of universities and laboratories. The detector will be installed in the Soudan II underground laboratory in northern Minnesota. The TEC for CDMS is $8,600,000.
- The Kamioka Liquid Scintillator Anti-Neutrino Detector (KamLAND), the largest low-energy antineutrino detector ever built, will be located in the Kamiokande mine in Japan. This detector will attempt to detect whether neutrinos have mass by searching for neutrino oscillations by studying the flux and energy spectra of neutrinos produced by Japanese commercial nuclear reactors. KamLAND is being done in collaboration with a number of Japanese groups. KamLAND is still undergoing program office review. The projected TEC for KamLAND is $3,000,000 to be provided by the HEP and NP programs.
- The Pierre Auger Project (Auger) is intended to detect and study very high energy cosmic rays using a very large array of surface detectors spread over 30,000 square kilometers. Auger is being done by a large international collaboration. The presently approved part of the project includes an array at a site in Argentina. The U.S. will provide only a modest portion of the cost of the Argentine array. The TEC for the U.S. portion of this phase of Auger is $3,000,000.
- The Very Energetic Radiation Imaging Telescope Array System (Veritas) will be a ground based high energy cosmic gamma ray detector designed to search for and study astrophysical gamma ray sources. As such, it will complement GLAST. The Veritas

	(dollars in thousands)	
FY 1999	FY 2000	FY 2001

collaboration includes both U.S. and foreign groups, and will be built at a site in Arizona. The TEC for the U.S. portion of Veritas is $6,000,000.

- The AntiMatter in Space (AMS) experiment was designed to detect antimatter and was operated on a space shuttle flight. The experiment performed well and the data are being analyzed. It is planned to upgrade the detector for a second shuttle flight. The TEC for the DOE portion of the AMS upgrade is $3,000,000.

Large Hadron Collider

In FY 1999 and FY 2000, funding was used for: R&D and measurement/testing on superconducting materials, cable, and wire; calculations and R&D on accelerator physics issues regarding the design, instrumentation, and prototypes of the magnets for the colliding beam intersection regions and RF accelerating regions. Activities on the detectors will include R&D and prototype development of subsystems such as tracking chambers, calorimeters, and data acquisition electronics.

The LHC work is being performed at various locations including 4 major DOE labs and more than 55 U.S. universities.

LHC Accelerator and Detector Funding Summary

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
High Energy Physics Facilities			
LHC			
Accelerator Systems			
Operating Expenses	1,205	740	2,200
Capital Equipment	14,195	19,360	15,600
Total, Accelerator Systems	15,400	20,100	17,800
Procurement from Industry	8,091	13,106	18,503
ATLAS Detector			
Operating Expenses	4,792	5,570	5,738
Capital Equipment	4,207	10,924	10,769
Total, ATLAS Detector	8,999	16,494	16,507
CMS Detector			
Operating Expenses	13,472	9,100	8,480
Capital Equipment	19,038	11,200	8,710
Total, CMS Detector	32,510	20,300	17,190
Total, LHC	65,000	70,000	70,000

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
▪ **Accelerator Systems**—In FY 2001, funding will support continued production of interaction region quadrupole magnets, dipole magnets, feedboxes, and absorbers; production of radio-frequency region dipole magnets; and completion of fabrication of the superconducting cable for these magnets. Production testing of wire and cable for the LHC main magnets and accelerator physics calculations will continue.	15,400	20,100	17,800
▪ **Procurement from Industry**—In FY 2001, funding will continue to support reimbursement to CERN for purchases from U.S. industry including superconducting wire, cable, and cable insulation materials.	8,091	13,106	18,503
▪ **ATLAS Detector**—In FY 2001, funding will support production of detector hardware and electronics. The barrel cryostat procurement for the liquid argon			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
calorimeter will be completed and procurement and testing will continue for the silicon strip electronics, and the transition radiation tracker electronics. Fabrication efforts will continue for the silicon strip modules, the forward calorimeter, the extended barrel tile calorimeter modules and submodules, the endcap monitored drift tubes, and the cathode strip chambers. Fabrication will be completed for the liquid argon calorimeter feed-throughs and motherboards and installation will begin.	8,999	16,494	16,507
▪ **CMS Detector**—In FY 2001, funding will support full rate production and testing of endcap muon system chambers and the procurement of the electronics and cables for the muon system. The hadron calorimeter barrel will be completed and delivered to CERN and the scintillator and brass absorber assembly will continue along with the testing of the associated electronics. The trigger designs will be completed and testing of the electronics will continue. The data acquisition system will complete prototyping efforts and continue test beam studies. The forward pixel system will complete advanced testing and prepare for production of readout chips and sensors.	32,510	20,300	17,190
Total, Large Hadron Collider	65,000	70,000	70,000
▪ **Waste Management ¾** Provides funding for packaging, shipment and disposition of hazardous, radioactive or mixed waste generated in the course of normal operations at Fermilab, SLAC, and beginning in FY 2001, LBNL. The laboratories continue to explore opportunities to reduce the volume of newly generated waste and its associated management and disposal costs.	4,910	4,910	10,410
▪ **SBIR/STTR ¾** In FY 1999, $13,972,000 was transferred to the SBIR program and $838,000 was transferred to the STTR program. Includes $13,839,000 for the SBIR program and $830,000 for the STTR program in FY 2000			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
and $7,785,000 for SBIR in FY 2001. The balance of the SBIR and STTR allocations for FY 2001 are included in the Research and Technology subprogram.	0	14,669	7,785
Total, High Energy Physics Facilities	444,825	439,853	444,610

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
▪ **Fermilab**	
‣ At Fermilab, a reduction of $2,734,000 in Operations resulting in a 7 week reduction in the projected running schedule as the upgraded CDF and D-Zero detectors are completed.	-2,734
‣ At Fermilab, increases of $1,132,000 in capital equipment funding for the MINOS detector and $4,931,000 in other capital equipment funding are offset by reductions of $4,879,000 in capital equipment funding for the CDF Upgrade, and $4,355,000 in capital equipment funding for the D-Zero Upgrade. The increase in other capital equipment is needed for anticipated hardware needs to correct problems appearing during the final commissioning of the Tevatron and Main Injector and to begin to meet second priority capital equipment needs in the laboratory that were deferred in previous years to make funding available for the large detectors.	-3,171
Total, Fermilab	-5,905
▪ **Stanford Linear Accelerator Center**	
‣ At SLAC, an increase of $300,000 in Operations. This only partly offsets the impact of inflation resulting in a decrease of 3 weeks in the projected running schedule.	+300
‣ At SLAC, the reduction of $1,220,000 in Support and Infrastructure is primarily a reduction in capital equipment funding reflecting an anticipated reduction in the need for new ancillary accelerator equipment since the B-factory is a new machine.	-1,220
Total, Stanford Linear Accelerator Center	-920

	FY 2001 vs. FY 2000 ($000)
▪ **Brookhaven National Laboratory**	
‣ At BNL, an increase of $2,430,000 to support AGS operation to complete the muon magnetic moment experiment and the initial testing of the rare kaon decay experiment in advance of full operation in FY 2002.	+2,430
‣ At BNL, an increase of $180,000 in capital equipment funding to support the planned upgrade of the rare kaon decay experiment.	+180
Total, Brookhaven National Laboratory	+2,610
▪ **Other Facility Support**	
‣ Decreases in capital equipment funding at ANL ($15,000) and LBNL ($45,000).	-60
‣ An increase in capital equipment funding provides funds primarily for fabrication of five non-accelerator major items of equipment assigned to the university based Physics Research program.	+5,500
‣ An increase of $5,000,000 to provide for the establishment of an enhanced capability for large scale computational modeling and simulation.	+5,000
‣ A reduction of $84,000 in the funds held in reserve pending completion of peer review and programmatic consideration.	-84
Total, Other Facility Support	+10,356
▪ **Waste Management**	
‣ In Waste Management, an increase of $5,500,000 reflecting the transfer of Waste Management responsibility at LBNL to the HEP budget from Environmental Management in FY 2001.	+5,500
▪ **SBIR/STTR**	
‣ A reduction of $6,884,000 in funding for SBIR and STTR reflecting the transfer of about half of the SBIR/STTR funding to the Research and Technology subprogram. The combined overall change in SBIR/STTR is $335,000.	-6,884
Total Funding Change, High Energy Physics Facilities	+4,757

Construction

Mission Supporting Goals and Objectives

This provides for the construction of major new facilities needed to meet the overall objectives of the High Energy Physics Program.

Performance Measures

- Make progress on the Neutrinos at the Main Injector project as measured by accomplishment of scheduled milestones as detailed in the benchmark plan.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Construction	21,000	28,700	32,400	+3,700	+12.9%

Detailed Program Justification

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
Neutrinos at the Main Injector (NuMI)¾ This project provides for the construction of new facilities at Fermilab and at the Soudan Underground Laboratory in Soudan, Minnesota that are specially designed for the study of the properties of the neutrino and in particular to search for neutrino oscillations. The FY 2001 funding is for construction of the neutrino production target, neutrino focusing horns, beam tunnel, underground detector and detector halls, and surface buildings at Fermilab.	14,300	22,000	23,000
Wilson Hall Safety Improvement Project (Fermilab)—This project provides for urgently needed rehabilitation of the main structural elements of Wilson Hall, and for urgently needed rehabilitation of windows, plumbing, the roof and the exterior of the building.	6,700	4,700	4,200

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
SLAC Research Office Building—This project provides urgently needed office space for the substantial expansion of visiting scientists, or "users", resulting from the B-factory becoming operational. The visiting user population is projected to increase from 200 visitors per year to 1,100 visitors per year. The new building will provide about 30,000 square feet and will be completed in FY 2001	0	2,000	5,200
Total, Construction	21,000	28,700	32,400

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
▪ Continuation of the Fermilab NuMI project on the planned profile.	+1,000
▪ Provides for completion of the Wilson Hall Safety Improvement Project at Fermilab on the planned profile	-500
▪ Provides for completion of the Research Office Building on the planned profile.	+3,200
Total Funding Change, Construction	+3,700

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
General Plant Projects	15,185	12,500	12,500	0	0.0%
Accelerator Improvements Projects........	7,231	8,900	8,880	-20	-0.2%
Capital Equipment.................................	92,315	89,167	84,329	-4,838	-5.4%
Total, Capital Operating Expense..........	114,731	110,567	105,709	-4,858	-4.4%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1999	FY 2000	FY 2001	Unapprop-riated Balance
98-G-304 Neutrinos at the Main Injector	76,200	5,500	14,300	22,000	23,000	11,400
99-G-306 Wilson Hall Safety Improvements......................................	15,600	0	6,700	4,700	4,200	0
00-G-307 SLAC Research Office Building..	7,200	0	0	2,000	5,200	0
Total, Construction...............................		5,500	21,000	28,700	32,400	11,400

Major Items of Equipment *(TEC $2 million or greater)*

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appropriations	FY 1999	FY 2000	FY 2001	Acceptance Date
D-Zero Upgrade....................	57,902	44,092	8,455	4,855	500	FY 2001
CDF Upgrade	56,916	41,482	9,555	5,379	500	FY 2001
B-factory Detector (BaBar) [a]...	68,000	64,200	3,800	0	0	FY 1999
Large Hadron Collider — Machine	87,340	11,785	14,195	19,360	15,600	FY 2005
Large Hadron Collider — ATLAS Detector....................	56,416	6,198	4,207	10,924	10,769	FY 2005
Large Hadron Collider — CMS Detector.......................	70,125	5,517	19,038	11,200	8,710	FY 2005
MINOS................................	45,709	0	2,600	5,868	7,000	FY 2004
GLAST [b]..............................	28,000	0	0	3,000	4,600	FY 2005
Cryogenic Dark Matter Search (CDMS)	8,600	0	0	0[c]	1,750	FY 2007
KamLAND [d]..........................	3,000	0	0	0[n]	800	FY 2002
Auger..................................	3,000	0	0	0[n]	1,250	FY 2003
Veritas [e]	6,000	0	0	0[n]	1,500	FY 2005
Antimatter in Space (AMS) Upgrade	3,000	0	0	0[n]	1,000	FY 2003
Total, Major Items of Equipment............................		173,274	61,850	60,586	53,979	

[a] The funding for the B-factory detector reflects cost savings of about $20,000,000 resulting from contributions of components and subsystems by non-U.S. collaborating institutions.

[b] Total estimated cost is subject to further negotiations with NASA and potential foreign collaborators.

[c] These major items of equipment were recently reviewed and recommended for initiation in FY 2000. HEP currently plans to support these major items of equipment that were approved after the FY 2000 budget was submitted to Congress.

[d] Funding split equally between High Energy Physics and Nuclear Physics budgets. KamLAND is only being shown on High Energy Physics table to display total TEC of $3,000,000.

[e] Approval still pending Program Office peer-review.

98-G-304, Neutrinos at the Main Injector (NuMI), Fermi National Accelerator Laboratory, Batavia, Illinois

(Changes from FY 2000 Congressional Budget Request are denoted with a vertical line [|] in the left margin.)

Significant Changes

Total Project Cost and the Completion Date have been adjusted due to changes in the MINOS detector profile.

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 1998 Budget Request *(A-E and technical design only)*.........................	1Q '98	4Q '98	NA	NA	5,500	6,300
FY 1999 Budget Request (Preliminary Estimate)...	--	3Q '99	1Q '99	4Q '02	75,800	135,300
FY 2000 Budget Request	3Q '98	2Q '00	3Q '99	2Q '03	76,200	136,100
FY 2001 Budget Request	3Q '98	2Q '00	3Q '99	2Q '04	76,200	138,600

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Design & Construction			
1998	5,500	5,500	1,140
1999	14,300	14,300	5,846
2000	22,000	22,000	26,300
2001	23,000	23,000	27,000
2002	11,400	11,400	11,900
2003	0	0	4,014

3. Project Description, Justification and Scope

The project provides for the design, engineering and construction of new experimental facilities at Fermi National Accelerator Laboratory in Batavia, Illinois and at the Soudan Underground Laboratory at Soudan, Minnesota. The project is called NuMI which stands for Neutrinos at the Main Injector. The purpose of the project is to provide facilities that will be used by particle physicists to study the properties of neutrinos, which are fundamental elementary particles. In the Standard Model of elementary particle physics there are three types of neutrinos that are postulated to be massless and to date, no direct experimental observation of neutrino mass has been made. However, there are compelling hints from experiments that study neutrinos produced in the sun and in the earth's atmosphere that indicate that if neutrinos were capable of changing their type it could provide a credible explanation for observed neutrino deficits in these experiments.

The primary element of the project is a high flux beam of neutrinos in the energy range of 1 to 40 GeV. The technical components required to produce such a beam will be located on the southwest side of the Fermilab site, tangent to the new Main Injector accelerator at the MI-60 extraction region. The beam components will be installed in a tunnel of approximately 1 km in length and 6.5 m diameter. The beam is aimed at two detectors (MINOS) which will be constructed in experimental halls located along the trajectory of the neutrino beam. One such detector will be located on the Fermilab site, while a second will be located in the Soudan Underground Laboratory. Two similar detectors in the same neutrino beam and separated by a large distance are an essential feature of the experimental plan.

The experiments that are being designed to use these facilities will be able to search for neutrino oscillations occurring in an accelerator produced neutrino beam and hence determine if neutrinos do have mass. Fermilab is the only operational high energy physics facility in the U.S. with sufficiently high energy to produce neutrinos which have enough energy to produce tau leptons. This gives Fermilab the unique opportunity to search for neutrino oscillations occurring between the muon and the tau neutrino. Additionally, the NuMI facility is designed to accommodate future enhancements to the physics program that could push the search for neutrino mass well beyond the initial goals established for this project.

4. Details of Cost Estimate [a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs	7,150	7,150
Design Management costs (0.0% of TEC)	10	10
Project Management costs (0.0% of TEC)	20	20
Total, Engineering design inspection and administration of construction costs (9.4% of TEC)	7,180	7,180
Construction Phase		
Buildings	8,320	8,320
Special Equipment	10,120	10,120
Other Structures	30,960	30,960
Construction Management (6.0% of TEC)	4,590	4,590
Project Management (2.8% of TEC)	2,170	2,170
Total, Construction Costs	56,160	56,160
Contingencies		
Design Phase (2.8% of TEC)	2,172	2,172
Construction Phase (14.0% of TEC)	10,688	10,688
Total, Contingencies (16.8% of TEC)	12,860	12,860
Total, Line Item Cost (TEC)	76,200	76,200

5. Method of Performance

Design of the facilities will be by the operating contractor and subcontractor as appropriate. To the extent feasible, construction and procurement will be accomplished by fixed-price contracts awarded on the basis of competitive bids.

[a] The annual escalation rates assumed for FY 1996 through FY 2002 are 2.5, 2.8, 3.0, 3.1, 3.3, 3.4, and 3.4 percent respectively.

6. Schedule of Project Funding

	(dollars in thousands)					
	Prior Years	FY 1999	FY 2000	FY 2001	Outyears	Total
Project Cost						
Facility Cost						
Total, Line item TEC..............................	1,140	5,846	26,300	27,000	15,914	76,200
Other Project Costs						
Capital equipment [a]...............................	0	2,560	5,868	7,000	30,281	45,709
R&D necessary to complete construction [b]	1,260	40	0	0	0	1,300
Conceptual design cost [c].......................	830	0	0	0	0	830
Other project-related costs [d]..................	1,520	1,960	5,632	3,382	2,067	14,561
Total, Other Project Costs............................	3,610	4,560	11,500	10,382	32,348	62,400
Total Project Cost (TPC)..............................	4,750	10,406	37,800	37,382	48,262	138,600

[a] Costs to fabricate the near detector at Fermilab and the far detector at Soudan. Includes systems and structures for both near detector and far detector, active detector elements, electronics, data acquisition, and passive detector material.

[b] This provides for project conceptual design activities, for design and development of new components, and for the fabrication and testing of prototypes. R&D on all elements of the project to optimize performance and minimize costs will continue through early stages of the project. Specifically included are development of active detectors and engineering design of the passive detector material. Both small and large scale prototypes will be fabricated and tested using R&D operating funds.

[c] Includes operating costs for development of conceptual design and scope definition for the NuMI facility. Also includes costs for NEPA documentation, to develop an Environmental Assessment, including field tests and measurements at the proposed construction location.

[d] Include funding required to complete the construction and outfitting of the Soudan Laboratory for the new far detector by the University of Minnesota.

7. Related Annual Funding Requirements

(FY 2003 dollars in thousands)

	Current Estimate	Previous Estimate
Annual facility operating costs [a]	500	500
Utility costs (estimate based on FY 1997 rate structure) [b]	500	500
Total related annual funding	1,000	1,000
Total operating costs *(operating from FY 2003 through FY 2007)*	5,000	5,000

[a] Including personnel and M&S costs (exclusive of utility costs), for operation, maintenance, and repair of the NuMI facility.

[b] Including incremental power costs for delivering 120 GeV protons to the NuMI facility during Tevatron collider operations, and utility costs for operation of the NuMI facilities, which will begin beyond FY 2002.

99-G-306, Wilson Hall Safety Improvements Project, Fermi National Accelerator Laboratory, Batavia, Illinois

(Changes from FY 2000 Congressional Budget Request are denoted with a vertical line [|] in the left margin.)

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 1999 Budget Request	1Q ‘99	2Q ‘00	3Q ‘99	3Q ‘02	15,600	18,800
FY 2000 Budget Request	1Q ‘99	2Q ‘00	3Q ‘99	3Q ‘02	15,600	18,800
FY 2001 Budget Request	1Q ‘99	2Q ‘00	3Q ‘99	3Q ‘02	15,600	18,800

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Construction			
1999	6,700	6,700	674
2000	4,700	4,700	6,340
2001	4,200	4,200	6,990
2002	0	0	1,596

3. Project Description, Justification and Scope

Wilson Hall, constructed in 1972, is the central laboratory facility for the Fermilab site. It is a 17 story reinforced concrete building with a 16 story atrium. The great majority of its area is devoted to office space. In addition, the building contains the cafeteria, the communications center, medical office, some light industrial and shop areas, and an 800 seat auditorium.

The Wilson Hall Safety Improvements Project is a comprehensive project to remediate the deficiencies in this facility. Among the causes for the deficiencies are the age of the building and its systems, safety issues and updating to current code standards, and building components and systems that have reached their useful life expectancy.

The structural deficiencies are currently resulting in the ongoing safety issue of falling concrete debris in occupied areas of the building, and will eventually threaten the integrity of the entire facility. Additional spalling of the concrete could occur on the exterior faces of the building. The current glazing in the sloped window walls is not the code required safety glass. Breakage could result in the falling of sharp edged shards of glass into the atrium area. The quality of the existing drinking water is poor (taste & color) resulting in low usage which allows levels of lead and copper to exceed regulatory requirements.

The building structure portion of this project provides for the rehabilitation of the existing concrete structure at the crossover bays, which connect the two towers that comprise Wilson Hall. The joints between the crossover bays and tower are experiencing significant structural degradation, resulting in the ongoing safety issue of falling debris and the probability of continued deterioration of the joints. Recent computer analysis of the movement of the building structure has indicated that the joints need to be reworked to allow for the seasonal movement caused by temperature changes. This project will implement the solution to the joint erosion problem. It will consist of reconstructing the joints (assuring effective independent movement of each tower). Since a number of areas in the building will have restricted occupancy while the repairs are being made, this project will include the staff relocation required to accommodate the construction as part of Other Project Costs. At the completion of the structural joint repairs, a thorough exterior inspection will be conducted and any necessary repairs completed.

The building envelope portion of this project provides for the weatherproofing of components of the building shell that are currently allowing water penetration, the refurbishment of the existing skylight system, refinishing and partially reglazing the north and south curtain walls, and replacing the exterior entrances, including the entrance plaza:

Entry Plaza: The plaza that covers the "catacomb" area will have clear sealer applied to the sloped portions of the concrete walls enclosing the catacombs. The raised plaza portions will have waterproofing and pavers installed over the existing concrete. The existing paving at the entrance plaza will be removed and a new waterproof membrane and new paving will be installed.

North and South Curtain Wall: The north and south curtain walls of Wilson Hall are comprised of an anodized aluminum framing system that extends the full height of the building. The lower six floors of the system are sloped but do not have the current code required safety glazing. The finish of the aluminum framing is deteriorating and the system is allowing water penetration into the building. Safety glazing will be installed and the system will be repaired to resolve the water penetration.

4. Details of Cost Estimate [a]

(dollars in thousands)

	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs	840	920
Project Management costs (0.8% of TEC)	130	100
Total, Engineering design inspection and administration of construction costs (6.2% of TEC)	970	1,020
Construction Phase		
Buildings	8,520	8,850
Inspection, design and project liaison, testing, checkout and acceptance	810	870
Construction Management (10.6% of TEC)	1,660	1,820
Project Management (2.6% of TEC)	400	430
Total, Construction Costs	11,390	11,970
Contingencies		
Design Phase (1.6% of TEC)	250	170
Construction Phase (19.2% of TEC)	2,990	2,440
Total, Contingencies (20.8% of TEC)	3,240	2,610
Total, Line Item Cost (TEC)	15,600	15,600

5. Method of Performance

Overall project management, quality assurance, supervision of design and construction efforts and coordination with the U.S. Department of Energy for this project will be the responsibility of the Fermi National Accelerator Laboratory, through the Facilities Engineering Services Section (FESS). Design will be accomplished by a combination of FESS staff and consultant A/E fixed price contracts under the direction of the Facilities Engineering Services Section. Construction for project completion will be accomplished by means of one or more competitively bid, fixed price construction subcontracts. Construction Management and overall project management during the construction phase of this project will remain the responsibility of the Facilities Engineering Services Section of the Fermi National Accelerator Laboratory.

[a] The economic escalation rates from FY 1997 dollars for FY 1999 through FY 2001 are 5.3%, 2.9%, and 2.9% respectively from the Department Price Change Index FY 1999 Guidance, General Construction.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Years	FY 1999	FY 2000	FY 2001	Outyears	Total
Project Cost						
Facility Cost						
Total, Line item TEC	0	674	6,340	6,990	1,596	15,600
Other Project Costs						
Conceptual design cost	1,100	0	0	0	0	1,100
Other project-related costs [a]	0	490	350	850	410	2,100
Total, Other Project Costs	1,100	490	350	850	410	3,200
Total Project Cost (TPC)	1,100	1,164	6,690	7,840	2,006	18,800

7. Related Annual Funding Requirements

	Current Estimate	Previous Estimate
Wilson Hall related annual costs	NA	NA
Incremental utility costs (estimate based on FY 1997 rate structure)	NA	NA
Total related annual funding *(operating from FY 2003 through FY 2007)* [b]	NA	NA

[a] Includes funding for relocation of tenants before and after the construction and rebuilding of their workspaces; refurbishment of existing elevators which will be used for construction purposes, and then restored to public use.

[b] No incremental annual operating costs will result from the completion of this project.

00-G-307, Research Office Building, Stanford Linear Accelerator Center, Stanford, California

(Changes from FY 2000 Congressional Budget Request are denoted with a vertical line [|] in the left margin.)

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 2000 Budget Request	1Q '00	3Q '00	4Q '00	4Q '01	7,200	7,430
FY 2001 Budget Request	1Q '00	3Q '00	4Q '00	4Q '01	7,200	7,430

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Construction			
2000	2,000	2,000	950
2001	5,200	5,200	6,250

3. Project Description, Justification and Scope

The new Research Office Building project will construct a two-story building with approximately 30,000 gross square feet that will provide permanent, energy efficient office and conference space to meet the needs of the Laboratory. The office building will be located immediately adjacent to and north of the existing SLAC Administrative and Engineering building in the central campus area of the Laboratory. The new government-owned facility described herein will be located on leased land. Features include fixed and flexible office areas, meeting rooms and conference facilities equipped with interior office furnishings. Conventional utilities, such as domestic water, sanitary sewer, HVAC, and electrical power, will be provided by short connections from existing services. Specialized utilities include HVAC control and equipment, telecommunication for video and computers, and the main electrical feed. Construction of this building may allow the demolition of several very old, temporary structures, totaling approximately 17,000 square feet.

This building will provide adequate facilities for the BaBar experimental program. This experimental program is critical to delivering the scientific understanding necessary to the success of the DOE's and the Nation's long-term science objective of maintaining the U.S. high energy physics program at the forefront of basic research.

With the increasing level of activity associated with the BaBar collaboration and SLAC's on-going high energy physics (HEP) experimental program, SLAC's space requirements are projected to exceed the capacity of currently existing office and meeting facilities. The BaBar experiment, which began operation in FY 1999, projects a large influx of users who will require adequate office and support space. SLAC expects to host approximately 1,100 HEP users per year as the BaBar experiment ramps up to full scale operations. The BaBar collaboration itself, consists of over six hundred users from around the world representing over seventy institutions. Office and meeting space is urgently needed to meet the demand created by this mega-collaboration. In the past, SLAC has only had about 200 collaborators/users in residence at any one time. Even at this level, most are housed in less than adequate facilities (the user community has become ever more vocal about this in the past year or two). In the BaBar era, SLAC expects substantially more users to be in residence and, as a national user facility, SLAC needs to be in a position to provide adequate space for them.

SLAC has investigated leasing and conversion alternatives to meet the projected need for office space but none has been judged to be as cost effective or satisfactory as the addition of the new office building. It was determined that there was insufficient off-site office space available nearby for leasing (12,000 square feet with a rental cost of $1,000,000 per year was available). Conversion of existing temporary and permanent facilities is not cost effective because the cost of renovation and necessary seismic and ADA work is roughly equal to the cost of new construction and the resulting space is inferior to new space specifically designed for office use. Additionally, valuable industrial space would be lost.

The use of substandard facilities could meet approximately two-thirds of this projected need but at substantial cost for necessary remedial work. With improved operating and energy efficiencies, it is estimated that the annual operating costs for this 30,000 square foot building will be equal to the current operating costs of the 17,000 square feet of temporary space to be removed.

If the new Research Office Building is not constructed, operating efficiencies and cost savings cannot be achieved, existing temporary structures, which are maintenance intensive and energy inefficient cannot be eliminated, the cost of seismic and ADA retrofitting will not be avoided, and parking will continue to be an operational deficiency in the main Computer Center area. Vehicular and pedestrian safety will not be improved. Commitments made to Stanford University and the SLAC HEP user population will not be met. An estimated $2,000,000 of avoidable costs will be incurred.

4. Details of Cost Estimate [a]

	(dollars in thousands) Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs	419	419
Design Management costs (1.4% of TEC)	98	98
Project Management costs (1.4% of TEC)	98	98
Total, Design Phase (8.5% of TEC)	615	615
Construction Phase		
Building	4,727	4,727
Specialized Utilities	519	519
Standard Equipment	496	496
Construction Management (1.6% of TEC)	113	113
Project Management (1.2% of TEC)	85	85
Total, Construction Costs	5,940	5,940
Contingencies		
Design Phase (0.8% of TEC)	61	61
Construction Phase (8.1% of TEC)	584	584
Total, Contingencies (9.0% of TEC)	645	645
Total, Line Item Cost (TEC)	7,200	7,200

5. Method of Performance

Construction and procurement shall be accomplished by fixed price subcontracts on the basis of competitive bidding. Design and inspection shall be performed by the laboratory and contracted Architect-Engineers.

[a] Escalated to mid-point of construction with a factor of 1.0611. Allocated Indirects included in costs.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Years	FY 1999	FY 2000	FY 2001	Outyears	Total
Project Cost						
Facility Cost						
Design	0	0	615	0	0	615
Construction	0	0	335	6,250	0	6,585
Total Facility Costs (TEC)	0	0	950	6,250	0	7,200
Other Project Costs						
Conceptual design cost	0	30	0	0	0	30
Other project related costs [a]	0	0	0	200	0	200
Total, Other Project Costs	0	30	0	200	0	230
Total Project Cost (TPC)	0	30	950	6,450	0	7,430

7. Related Annual Funding Requirements

(FY 2002 dollars in thousands)

	Current Estimate	Previous Estimate
Annual facility maintenance/repair costs [b]	39	34
Incremental utility costs [c]	41	36
Total related annual funding	80	70
Total Operating costs (operating from FY 2003 through FY 2007)	400	350

[a] Includes funding for demolition of temporary structures; paving.

[b] Includes costs for janitorial services.

[c] Includes incremental utility costs for electric power and water.

Nuclear Physics

Program Mission

The Nuclear Physics program of the Department of Energy (DOE) has the lead responsibility for Federal support of nuclear physics research and supports fundamental research activities under the mandate provided in Public Law 95-91 that established the Department. The primary mission of the program is to support the basic research scientists, develop and operate the facilities, and foster the technical and scientific activities needed to understand the structure and interactions of atomic nuclei, and the fundamental forces and particles of nature as manifested in nuclear matter. Atomic nuclei can be described as a collection of nucleons (protons and neutrons), bound together by the mechanism of exchange of mesons, mainly pi mesons (pions). The research forefront in nuclear physics now includes incorporation of the quark substructure of the nucleon into the understanding of nuclear structure and of quark-antiquark pairs to form the mesons. Quarks, which are the most elementary building blocks of matter, are bound together in groups of three by the exchange of gluons to form the nucleons.

Attendant upon this core mission are responsibilities to enlarge and diversify the Nation's pool of technically trained talent and to facilitate transfer of technology and knowledge acquired to support the Nation's economic base. The program works in close coordination with the Nuclear Physics program at the National Science Foundation (NSF) and, jointly with the NSF, charters the Nuclear Science Advisory Committee to provide advice on scientific opportunities and priorities.

The high quality of the research in this program is continuously evaluated through the use of merit based peer review and scientific advisory committees.

Program Goal

Understand the properties and behavior of atomic nuclei and nuclear matter, and the fundamental forces involved, based on a series of systematic experimental and theoretical scientific investigations.

Program Objectives

- Conduct a program of maximum effectiveness to provide new insights into the nature of energy and subatomic matter, based on evaluation by rigorous peer review.
- Conceive, develop, construct, and operate world class scientific accelerator facilities in a timely and effective manner. In the execution of this responsibility, together with other Office of Science organizations, act as the Nation's leader in developing management techniques to optimize construction and operation of facilities in a cost effective, safe, and environmentally responsible manner.
- Leverage United States objectives by means of international cooperation through exchanges of scientists and participation in cooperative projects.
- Continue the advanced education and training activities of young scientists to maintain the skills and conceptual underpinning of the Nation's broad array of nuclear related sciences and technologies.

Performance Measures

- Evaluate the scientific quality and capability of the total DOE Nuclear Physics program to maintain the United States position as world leader in nuclear physics research. Evaluations will be based on rigorous peer reviews conducted by recognized scientific experts.
- Determine the production trends of diverse, highly trained young scientists - an essential ingredient for the vitality of the nation's technological base - using the Nuclear Physics annual census of scientific personnel. Funding patterns of university grants will include consideration of the optimum production rate of scientists.
- Use the assistance of technical experts to monitor the performance of construction projects for world class nuclear physics facilities and instrumentation. Measure project performance against cost and schedule milestones contained in project plans. Working with the relevant DOE project manager and laboratory project management, identify and establish programmatic modifications needed to enable projects to meet schedules and costs.
- Select research projects through a peer-reviewed, merit-based competitive process.
- Use peer reviews and user feedback to monitor the effectiveness of facility operations. Evaluate facility performance against objectives set in program guidance based on funding availability, and measure achieved beam hour availability against guidelines. Develop appropriate facility funding profiles to best provide overall research productivity for the Nuclear Physics program. Operate research facilities in a manner that meets user requirements as indicated by achieving performance specifications while protecting the safety of the workers and the environment, and by the level of endorsement by user organizations.
- Measure the progress and success of the Nuclear Physics program in responding to priorities and recommendations contained within the long range plan of the DOE/NSF Nuclear Science Advisory Committee (NSAC), as measured by NSAC's evaluation letter to the Nuclear Physics program.
- Continue collaborative efforts with NASA to use beams at Brookhaven National Laboratory to study the effects of radiation on biological and electronic systems in space.
- Complete fabrication of the BLAST detector at MIT/Bates in FY 2001 in accordance with the established baseline and as measured against the detailed project milestones.

Significant Accomplishments and Program Shifts

- In FY 2000, the Nuclear Physics Program initiated an Outstanding Junior Investigator (OJI) program to recognize and support young promising scientists pursuing nuclear physics research.

Medium Energy Nuclear Physics

- In FY 1999, the Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility (TJNAF) provided beams up to 5.5 GeV to all three experimental halls for research with polarized and unpolarized beams. Application of improved conditioning of the accelerator cavities is expected to increase the energy to 6 GeV by FY 2001.
- Precision measurements performed with new world-class polarized electron beams at TJNAF in FY 1999 provide important new insight into the role of the strange quark in determining the fundamental properties of the nucleon.

- An international collaboration (HERMES), involving several US Nuclear Physics Groups, presented results in FY 1999 indicating that gluons are responsible for a significant fraction of the observed spin of the nucleon, based on measurements performed at the DESY accelerator in Germany.
- In FY 1999, over 80 milliamperes of a 660 MeV stored electron beam in the Bates South Hall Ring was directed through a hydrogen internal gas target at the location of the BLAST detector. This was a significant milestone in the development of capabilities for the planned BLAST research program.
- In FY 2001, the BLAST detector at the MIT/Bates Linear Accelerator Center facility will be completed and will initiate commissioning for a research program in FY 2002-2004 studying the structure of the nucleon and few-body nuclei. Upon completion of the BLAST research program in FY 2004, the Bates facility will begin a 2-year phaseout.
- In FY 2001, the Brookhaven Medium Energy Group will be re-directed to emphasize a program directed at understanding the origin of the spin of the proton at the new RHIC facility. A limited program of fixed target experiments will be supported at the AGS.

Heavy Ion Nuclear Physics

- In FY 1999, the following performance goal was fully met:
  - Complete construction and begin operation of the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory.
- In FY 1999, the Relativistic Heavy Ion Collider (RHIC) construction project at Brookhaven National Laboratory (BNL) was completed on schedule and within budget. In FY 2001, RHIC will approach full luminosity following initial operation in FY 2000. Fabrication of detectors, including the additional experimental equipment recommended by NSAC for purposes of particle detection and data analysis, will be largely completed, as scheduled. Four experiments (STAR, PHENIX, BRAHMS and PHOBOS) involving over 950 researchers and students from 90 institutions and 19 countries will pursue a vigorous research program.
- In FY 1999, observations of two new elements (Z=116 and 118) were reported in measurements performed at the LBNL 88-Inch Cyclotron using the Berkeley Gas-filled Spectrometer (BGS). Continued measurements are planned for FY 2000 and FY 2001.
- In FY 1999, the NSAC Isotope Separation On-Line (ISOL) Task Force, identified an optimal configuration for a next generation Rare Isotope Accelerator (RIA). RIA is a facility where short-lived nuclei (with lifetimes of greater than a thousandth of a second) are produced in nuclear reactions using intense beams of stable nuclei, then extracted and accelerated in a post-accelerator to be used in experiments. RIA would provide unique, world-class capabilities for the low energy, nuclear astrophysics and nuclear structure communities for several decades. R&D and preconceptual design activities will continue in FY 2000 and FY 2001.
- In FY 1999, Gammasphere coupled with the Fragment Mass Separator at the ANL ATLAS facility, provided surprising results on the structure of the Nobelium isotope (^{254}No) showing that nuclear shell structures, which are entirely responsible for the stability of nuclei with charges greater than 100, persist up to very high deformation.
- In FY 2000, Gammasphere will be moved from the ANL ATLAS facility to the LBNL 88-Inch Cyclotron facility for a research program that will utilize the capabilities of the 88-Inch Cyclotron.
- Measurements performed in FY 1999 at the ATLAS facility have established properties of nuclei and reaction processes that allow for more stringent tests of models for supernova collapses and improved predictions for chemical element production in stellar burning and supernovae.

- In FY 1999, researchers at the Texas A&M Cyclotron facility developed a new method for establishing very low energy proton capture cross sections that are critical to astrophysical modeling of the production of the chemical elements of our universe. This is expected to lead to significantly improved astrophysics predictions.

Low Energy Nuclear Physics

- The US/Canadian Sudbury Neutrino Observatory (SNO) detector was completed and initiated data taking in FY 1999. Initial results, of measurements of solar neutrinos fluxes relevant to the question of whether neutrinos have mass, are anticipated in FY 2001.
- In FY 1999, the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL) completed a series of experiments that provide input to refined astrophysical calculations for the breakout from the Carbon-Nitrogen-Oxygen (CNO) cycle responsible for element production beyond oxygen. An expanded series of measurements will be carried out in FY 2000-2001 as new beam species are developed and beam intensities increase.
- In FY 1999, at the ORNL Oak Ridge Electron Linear Accelerator (ORELA) facility, precision measurements of neutron capture cross sections on Neodymium and Barium isotopes have provided the critical data necessary to use precision meteorite abundance results to test the new astrophysical Red Giant Stardust Model for heavy element production.

Nuclear Theory

- University theorists made a significant step forward in our understanding of how and where the heavier elements observed in nature were originally produced with strong evidence that they were created in neutron rich gas at the core of supernova explosions.
- Theorists at universities and the national laboratories, in several collaborative efforts, have developed increasingly sophisticated models of the reactions between ultra relativistic heavy ions, such as will be produced in the Relativistic Heavy Ion Collider facility at the Brookhaven National Laboratory. In the past year, several new and potentially clear signals indicative of the creation of the quark-gluon plasma in such collisions were suggested by these models.
- Recently, national laboratory theorists have found, quite unexpectedly, that effects due to special relativity can explain a symmetry in the low lying states of nuclei that is observed in a large number of nuclei, but for which there was previously no satisfactory explanation.
- In FY 2001, the Nuclear Theory Institute at the University of Washington continues its activities as a premier international center for new initiatives and collaborations in nuclear theory research.

Scientific Facilities Utilization

The Nuclear Physics request includes $250,180,000 to maintain support of the Department's scientific user facilities. This funding will provide research time for thousands of scientists in universities, Federal agencies, and U.S. companies. It will also leverage both Federally and privately sponsored research consistent with the Administration's strategy for enhancing the U.S. National science investment.

Funding of Contractor Security Clearances

In FY 1999, the Department divided the responsibility for obtaining and maintaining security clearances. The Office of Security Affairs, which was responsible for funding all Federal and contractor employee clearances, now pays only for clearances of Federal employees, both at headquarters and the field.

Program organizations are now responsible for contractor clearances, using program funds. This change in policy enables program managers to make the decisions as to how many and what level clearances are necessary for effective program execution. In this way, it is hoped that any backlog of essential clearances which are impeding program success can be cleared up by those managers most directly involved. The Office of Science is budgeting $88,000 for estimated contractor security clearances in FY 2000 and FY 2001; respectively, within this decision unit.

Workforce Development

The Nuclear Physics program supports development of the R&D workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. The R&D workforce developed under this program not only provides new scientific talent in areas of fundamental research, but also in a wide variety of technical, medical, and industrial areas requiring the finely honed thinking and problem solving abilities and computing and technical skills developed through an education and experience in a fundamental research field. Scientists trained as Nuclear Physicists can be found in such diverse areas as hospitals (nuclear medicine and medical physics), space exploration, and the stock market.

The 814 post-doctoral Associates and graduate students supported by the Nuclear Physics program in FY 1999 were involved in a large variety of experimental and theoretical research. Nearly one third are involved in theoretical research. Those involved in experimental research utilize a number of scientific facilities supported by the DOE, NSF, and foreign countries. The majority of the 510 postdoctoral associates and graduate students doing experimental research in FY 1999 did their work at the six Nuclear Physics Scientific User Facilities: ATLAS (ANL), 88-Inch Cyclotron (LBNL), HRIBF (ORNL), Bates Accelerator Center (MIT), RHIC (BNL), and Jefferson Lab (TJNAF in Virginia).

Funding Profile

(dollars in thousands)

	FY 1999 Current Appropriation	FY 2000 Original Appropriation	FY 2000 Adjustments	FY 2000 Current Appropriation	FY 2001 Request
Nuclear Physics					
Medium Energy Nuclear Physics	115,695	121,250	-2,400	118,850	125,405
Heavy Ion Nuclear Physics.........	146,905	180,775	-1,365	179,410	192,360
Low Energy Nuclear Physics......	32,308	34,145	-366	33,779	33,970
Nuclear Theory..........................	15,640	15,830	-155	15,675	18,155
Subtotal, Nuclear Physics................	310,548	352,000	-4,286	347,714	369,890
Construction.............................	16,620	0	0	0	0
Subtotal, Nuclear Physics................	327,168	352,000	-4,286	347,714	369,890
Use of Prior Year Balances.........	-776[a]	0	0	0	0
General Reduction.....................	0	-2,407	2,407	0	0
Contractor Travel.......................	0	-695	695	0	0
Omnibus Rescission..................	0	-1,184	1,184	0	0
Total, Nuclear Physics.....................	326,392[b]	347,714	0	347,714	369,890[c]

Public Law Authorization:

Public Law 95-91, "Department of Energy Organization Act"

Public Law 103-62, "Government Performance Results Act of 1993"

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[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $6,969,000 that has been transferred to the SBIR program and $418,000 which has been transferred to the STTR program.

[c] Includes $5,957,000 for Waste Management activities at Brookhaven National Laboratory that was previously budgeted in FY 1999 and FY 2000 in the Environmental Management program.

Funding by Site

	FY 1999	FY 2000	FY 2001	$ Change	% Change
	(dollars in thousands)				
Albuquerque Operations Office					
Los Alamos National Laboratory	10,505	9,986	10,095	+109	+1.1%
Chicago Operations Office					
Argonne National Laboratory	17,039	16,304	16,965	+661	+4.1%
Brookhaven National Laboratory	117,305	132,463	145,783	+13,320	+10.1%
Chicago Operations Office	52,218	48,507	50,016	+1,509	+3.1%
Total, Chicago Operations Office	186,562	197,274	212,764	+15,490	+7.9%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	80	0	0	0	0.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	23,222	17,232	17,250	+18	+0.1%
Lawrence Livermore National Laboratory	710	564	785	+221	+39.2%
Oakland Operations Office	14,425	16,246	16,283	+37	+0.2%
Total, Oakland Operations Office	38,357	34,042	34,318	+276	+0.8%
Oak Ridge Operations Office					
Oak Ridge Institute for Science & Education	585	559	650	+91	+16.3%
Oak Ridge National Laboratory	16,094	15,173	16,120	+947	+6.2%
Thomas Jefferson National Accelerator Facility	71,673	72,730	74,715	+1,985	+2.7%
Oak Ridge Operations Office	123	81	64	-17	-21.0%
Total, Oak Ridge Operations Office	88,475	88,543	91,549	+3,006	+3.4%
Richland Operations Office					
Richland Operations Office	1,900	0	0	0	0.0%
Washington Headquarters	1,289	17,869	21,164	+3,295	+18.4%
Subtotal, Nuclear Physics	327,168	347,714	369,890	+22,176	+6.4%
Use of Prior Year Balances	-776[a]	0	0	0	0.0%
Total, Nuclear Physics	326,392[b]	347,714	369,890[c]	+22,176	+6.4%

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $6,969,000 that has been transferred to the SBIR program and $418,000 which has been transferred to the STTR program.

[c] Includes $5,957,000 for Waste Management activities at Brookhaven National that was previously budgeted in FY 1999 and FY 2000 in the Environmental Management program.

Site Description

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. At Argonne, the Nuclear Physics program supports: (1) the Heavy Ion group, which operates the ATLAS Heavy Ion accelerator as a national user facility, and carries out related research; (2) the Medium Energy group, which carries out a program of research at TJNAF, Fermilab, and DESY in Germany; also supported are activities leading to a "spin" physics program at RHIC; (3) R&D directed at a proposed advanced Rare Isotope Accelerator (RIA) facility; (4) the Nuclear Theory group which carries out theoretical calculations and investigations in subjects supporting the experimental research programs in Medium Energy and Heavy Ion physics; and (5) data compilation and evaluation activities as part of the national data program.

Brookhaven National Laboratory (BNL)

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The major effort at BNL, supported by the Heavy Ion Program, is the new Relativistic Heavy Ion Collider (RHIC) which uses the Tandem, Booster and Alternating Gradient Synchrotron (AGS) accelerators in combination as an injector. The RHIC facility is a major new and unique international user facility. RHIC will search for the predicted "quark-gluon plasma," a form of nuclear matter not previously observed. The Medium Energy program will use polarized protons in RHIC to understand the internal "spin" structure of the protons and pursue a limited program of fixed target experiments at the AGS. The Laser Electron Gamma Source (LEGS) group uses a unique polarized photon beam to carry out a program of photonuclear spin physics at the National Synchrotron Light Source (NSLS). The BNL Nuclear Theory group provides theoretical support and investigations primarily in the area of relativistic heavy ion physics. Low Energy support is provided for detector and chemical analysis development for the Sudbury Neutrino Observatory (SNO) and involvement in the SNO research program. BNL's DOE-managed National Nuclear Data Center is the central U.S. site for the American and international nuclear data and compilation effort.

Idaho National Engineering & Environmental Laboratory (INEEL)

Idaho National Engineering and Environmental Laboratory is a Multiprogram Laboratory located on 572,000 acres in Idaho Falls, Idaho. At INEEL, the program of nuclear data and compilation directly supported by the Nuclear Physics program, has been phased out.

Lawrence Berkeley National Laboratory (LBNL)

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located in Berkeley, California. The Lab is on a 200 acre site adjacent to the Berkeley campus of the University of California. At LBNL, the Nuclear Physics program supports: (1) operations and research at the 88-inch Cyclotron, a heavy ion accelerator which is run as a national user facility; (2) the Relativistic Nuclear Collisions group, with activities primarily at RHIC, where they have been major players in the development of the large STAR detector; (3) the Low Energy group, which plays a major role in the implementation and operation of the Sudbury Neutrino Observatory (SNO) detector; (4) the Nuclear Theory group, which carries out a program with emphasis on theory of relativistic heavy ion physics; and (5) the Nuclear Data group whose activities support the National Nuclear Data Center at BNL.

Lawrence Livermore National Laboratory (LLNL)

Lawrence Livermore National Laboratory is a Multiprogram Laboratory located on a 821 acre site in Livermore, California. Low Energy Research support is provided for nuclear structure studies carried out primarily at the GENIE detector at the LANSCE facility at Los Alamos National Laboratory, and for nuclear data and compilation activities.

Los Alamos National Laboratory (LANL)

Los Alamos National Laboratory is a Multiprogram Laboratory located on a 27,000 acre site in Los Alamos, New Mexico. Nuclear Physics supports a broad program of research including: (1) a program of neutron beam research which utilizes beams from the LANSCE facility; (2) a relativistic heavy ion effort using the PHENIX detector at the new Relativistic Heavy Ion Collider (RHIC); (3) research directed at the study of the quark substructure of the nucleon in experiments at Fermilab, and at the "spin" structure of nucleons at RHIC using polarized proton beams; (4) the development of the Sudbury Neutrino Observatory (SNO) detector as well as involvement in the planned research program; (5) a broad program of theoretical research into a number of topics in nuclear physics; (6) nuclear data and compilation activities as part of the national nuclear data program.

Oak Ridge Institute for Science and Education (ORISE)

Oak Ridge Institute for Science and Education is located on a 150 acre site in Oak Ridge, Tennessee. Nuclear Physics support is provided through ORISE for activities in support of the Holifield Radioactive Ion Beam Facility (HRIBF) and its research program.

Oak Ridge National Laboratory (ORNL)

Oak Ridge National Laboratory is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The major effort at ORNL is the Low Energy program support for research and operations of the Holifield Radioactive Ion Beam Facility (HRIBF), which is run as a national user facility. HRIBF allows a program of experimental research in nuclear structure and reaction processes important for astrophysics. Also supported is a relativistic heavy ion group which is involved in a research program using the PHENIX detector at RHIC. The theoretical nuclear physics effort at ORNL emphasizes investigations of nuclear structure and astrophysics. Nuclear data and compilation activities are also supported as part of the national nuclear data effort.

Thomas Jefferson National Accelerator Facility (TJNAF)

Thomas Jefferson National Accelerator Facility (TJNAF) is a program-dedicated laboratory (Nuclear Physics) located on 273 acres in Newport News, Virginia. Major Medium Energy program support is provided for the operation and research program of TJNAF, a unique international user facility for the investigation of nuclear and nucleon structure based on the underlying quark substructure. Also supported is a nuclear theory group whose program of investigations support the experimental program of the laboratory. The Nuclear Physics program provides most of the support for this new single purpose laboratory.

All Other Sites

The Nuclear Physics program funds 160 research grants at 87 colleges/universities located in 35 states. Also included are funds for research awaiting distribution pending completion of peer review results.

Medium Energy Nuclear Physics

Mission Supporting Goals and Objectives

The Nuclear Physics Program supports the basic research necessary to identify and understand the fundamental features of atomic nuclei and their interactions. The Medium Energy Nuclear Physics subprogram supports fundamental research that is ultimately aimed at achieving an understanding of the structure of the atomic nucleus in terms of the quarks and gluons, the objects that are believed to combine in different ways to make all the other sub-atomic particles. Equally important is the achievement of an understanding of the "strong force;" one of only four forces in nature, and the force that holds the nucleus of the atom together. Research efforts include studies of the role of excited states of protons and neutrons in nuclear structure, investigations of the role of specific quarks in the structure of protons and neutrons, studies of the symmetries in the behavior of the laws of physics, and investigations of how the properties of protons and neutrons change when embedded in the nuclear medium. Measurements are often carried out with beams of electrons or protons whose "spins" have all been lined up in the same direction (polarizing the beams) to determine unique "structure functions," and other indicators of the details of nuclear structure.

This research is generally carried out using higher energy electron and proton beams provided by accelerator facilities operated by this subprogram, other Department of Energy programs (e.g., High Energy Physics and Basic Energy Sciences) and at other unique domestic or foreign facilities. The Medium Energy Nuclear Physics subprogram supports the operations of two national user facilities - the Thomas Jefferson National Accelerator Facility (TJNAF) and the Bates Linear Accelerator Center operated by the Massachusetts Institute of Technology. These accelerator facilities serve a nationwide community of Department of Energy and National Science Foundation supported scientists from over 100 American institutions, of which over 90% are universities. Both facilities provide major contributions to American education at all levels. At both TJNAF and Bates, the National Science Foundation (NSF) has made a major contribution to new experimental apparatus in support of the large number of NSF users. A significant number of foreign scientists collaborate in the research programs of both facilities. The research program at the new TJNAF, for example, involves over 250 scientists from 19 foreign countries; many of these scientists are from Conseil Europeen pour la Recherche Nucleaire (CERN) member states. At TJNAF, foreign collaborators have also made major investments in experimental equipment.

Performance Measures

- Complete fabrication of the BLAST detector at MIT/Bates in accordance with the project milestones.

Funding Schedule

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Research					
University Research	16,729	16,422	16,945	+523	+3.2%
National Laboratory Research	19,649	19,961	20,430	+469	+2.3%
Other Research	399[a]	5,067	5,355	+288	+5.7%
Subtotal, Research	36,777	41,450	42,730	+1,280	+3.1%
Operations					
TJNAF Operations	65,418	66,515	68,400	+1,885	+2.8%
Bates Operations	13,500	10,885	12,775	+1,890	+17.4%
Other Operations	0	0	1,500	+1,500	+100.0%
Subtotal, Operations	78,918	77,400	82,675	+5,275	+6.8%
Total, Medium Energy Nuclear Physics	115,695	118,850	125,405	+6,555	+5.5%

Detailed Program Justification

(dollars in thousands)		
FY 1999	FY 2000	FY 2001

Research

University Research

These activities comprise a broad program of research, and include 42 grants at 33 universities in 17 states and the District of Columbia. These research efforts utilize not only each of the accelerator facilities supported under the Medium Energy program, but also use other U.S. and international accelerator laboratories. Included in University Research is Bates Research, the effort performed at the MIT/Bates Linear Accelerator Center by MIT scientists. Other University Research includes all other university-based efforts using many research facilities, including activities by MIT scientists that are not carried out at Bates.

Bates Research:

- At the MIT/Bates accelerator, MIT scientists along with other university researchers have completed "symmetry violation" studies on the proton in the North Experimental Hall. "Out-of-Plane" measurements are being carried out using new spectrometers in the South

[a] Excludes $4,059,000 which has been transferred to the SBIR program and $418,000 which has been transferred to the STTR program.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Experimental Hall on the proton, deuteron, and complex nuclei including measurements of the transition of the proton to its excited state.			
‣ Preparations are being made for a new program of research utilizing the new BLAST large acceptance detector whose fabrication will be completed in FY 2001. BLAST will be used in conjunction with thin gas targets and the high current circulating electron beam in the South Hall Pulse Stretcher Ring.	4,700	4,500	4,200

Other University Research:

- University scientists are collaborating on important ongoing and future experiments at TJNAF. FY 2001 activities include the completion of studies of the charge structure of the neutron in Hall C, planned measurements include the electric form factor of the proton, and a series of planned studies of the excited states of the proton in Hall B. First parity-violation measurements to look for the "strange quark" content of the proton in Hall A have been completed. Plans are also underway to carry out a program of high resolution hypernuclear spectroscopy in Hall A. Scientists are participating in a major new detector being assembled for the "G0" experiment in cooperation with the National Science Foundation. "G0" will allow a "complete mapping" of the strange quark content of the nucleon using parity violation techniques.
- A number of university groups are collaborating in experiments using the new Out-of-Plane spectrometers in the South Experimental Hall at the MIT/Bates Linear Accelerator Center. BLAST will be completed in FY 2001 and university research support will be provided.
- University scientists and National Laboratory collaborators will continue to carry out the HERMES experiment at the DESY laboratory in Hamburg, Germany. This experiment is measuring what components of the proton or neutron determine the "spin" of these particles, an important and timely scientific issue. In FY 2001, HERMES will continue to utilize a new Ring Imaging Cerenkov counter for particle identification.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
▸ The Palo Verde neutrino detector has been searching for neutrino oscillations using the Palo Verde nuclear power reactors near Phoenix, Arizona as the source of neutrinos. Recent measurements suggesting that such oscillations exist, implying neutrinos have mass, have a major impact on our understanding of the laws of physics. In FY 2001, the experimental program will be complete and data analysis will be underway.	12,029	11,922	12,745
Total, University Research...	16,729	16,422	16,945

National Laboratory Research

Included is: (1) the research supported at the Thomas Jefferson National Accelerator Facility (TJNAF), that houses the Nation's and World's unique high intensity continuous wave electron accelerator and (2) research efforts at Argonne, Brookhaven, and Los Alamos National Laboratories. The National Laboratory groups carry out research at various world facilities as well as at their home institutions.

TJNAF Research:

	FY 1999	FY 2000	FY 2001
▸ Scientists at TJNAF, with support of the user community, assembled the large and complex new experimental apparatus for Halls A, B, and C. All three experimental Halls are operational. TJNAF scientists provide experimental support and operate the apparatus for safe and effective utilization by the user community. TJNAF scientists participate in the laboratory's research program, and collaborate in research at other facilities. ▸ As of FY 2000, twelve experiments will have been completed in Hall C. Ten experiments will have been completed in Hall A. The complex large-acceptance spectrometer in Hall B is complete and the research program is well underway. Three major experiments will have been completed, and partial data will have been accumulated on many more. ▸ TJNAF scientists are participating in the assembly of a new detector for the "G0" experiment, in cooperation with the National Science Foundation.	5,760	5,680	5,800

(dollars in thousands)

FY 1999	FY 2000	FY 2001

Other National Laboratory Research:

- Argonne National Laboratory scientists are pursuing research programs at TJNAF, at the DESY Laboratory in Germany, and have proposed measurements of the quark structure of the nucleon at the new Main Injector at Fermilab. The theme running through this entire effort is the search for a detailed understanding of the internal structure of the nucleon.
- At Brookhaven National Laboratory, the Medium Energy Research group, that in previous years has concentrated on hadron beam experiments at the AGS, will change its emphasis. Since the AGS will now serve as a heavy ion and proton injector for the new RHIC accelerator, the group's scientific emphasis will shift to "RHIC Spin". This is the set of experiments planned for RHIC that will use colliding polarized proton beams to investigate the spin content of the nucleon. In FY 2001, additional funding is being provided to this group to assure that maximum scientific effort has been assembled in support of the RHIC Spin effort. A limited program of fixed target experiments will continue at the AGS, including an important study of hypernuclei for which the Japanese are major collaborators.
- Also at Brookhaven, Laser Electron Gamma Source (LEGS) scientists will be utilizing a new spectrometer and polarized target for a program of spin physics at low energies. This unique facility produces its high energy polarized "gammas" by back scattering laser light from the circulating electron beam at the National Synchrotron Light Source (NSLS). In FY 2001, the research program utilizing the new equipment will be fully underway.
- At Los Alamos National Laboratory, scientists and collaborators will be preparing to carry out a next generation neutrino oscillation experiment (BooNE), that builds on the experience of the Liquid Scintillator Neutrino Detector (LSND) experiment at Los Alamos that detected a signal of neutrino oscillations. If oscillations are proven, then neutrinos would have mass, requiring changes in our present understanding of the laws of physics. BooNE will be built at the Fermi

	FY 1999	FY 2000	FY 2001
National Accelerator Laboratory (Fermilab), and will use neutrinos generated by the proton beam from the Fermilab Booster.			
‣ Los Alamos National Laboratory scientists and collaborators are also developing unique cold and ultra-cold neutron facilities at the Los Alamos Neutron Science Center (LANSCE). Difficult new experiments using these "very low energy" techniques will be supported and promise to provide important new information on some of the fundamental laws of physics.			
‣ Los Alamos scientists will also continue to be involved in experiments at Fermilab and at RHIC (RHIC Spin), that continue to try to unravel the mysteries of the internal components and spin of the nucleon. The Los Alamos group has also been instrumental in providing major components of the PHENIX detector at RHIC, that are crucial in carrying out the RHIC-Spin program of research.	13,889	14,281	14,630
Total, National Laboratory Research	19,649	19,961	20,430

(dollars in thousands)

Other Research

Other Research: Amounts include funds for the FY 2000 and FY 2001 SBIR and STTR programs and other established obligations which the Medium Energy Nuclear Physics subprogram must meet.

	FY 1999	FY 2000	FY 2001
‣ In FY 1999 $4,059,000 and $418,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts include the estimated requirement for the continuation of the SBIR and STTR programs	399	5,067	5,355
Total, Research	36,777	41,450	42,730

Operations

TJNAF Operations

Included is the funding that supports: (1) operation of the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF), and (2) major manpower, equipment, and staging support for the assembly and dismantling of complex experiments.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001

TJNAF Accelerator Operations:

- The accelerator is now capable of delivering beams of differing energies and currents simultaneously to the three experimental halls. A maximum beam energy of 5.5 GeV has been delivered to experiments, and by FY 2001, 6 GeV will be readily available. Polarized beam capability is now also available and is being used for experiments.

	(hours of beam)		
	FY 1999	FY 2000	FY 2001
TJNAF...	4500	4500	4500

- AIP funding will provide for polarized injector and beam handling components that enable simultaneous polarized beam capability with varied operating parameters in the three experimental halls. AIP funding also supports other additions and modifications to the accelerator facilities. GPP funding is provided for minor new construction and utility systems.....................	41,500	42,405	44,075

TJNAF Experimental Support:

- Support is provided for the scientific and technical manpower, materials, and services needed to integrate rapid assembly, modification, and disassembly of large and complex experiments for optimization of schedules. This includes the delivery or dismantling of cryogenic systems, electricity, water for cooling, radiation shielding, and special equipment for specific experiments.
- The G0 detector, a major item of equipment with a Total Estimated Cost of $6,992,000 is being assembled. DOE's contribution is $3,387,000 and the National Science Foundation is contributing $3,605,000 to this detector. Capital equipment funding is also being used for assembly and installation of polarized electron injector improvements for the accelerator. Capital equipment funds will be used to install other ancillary equipment items such as polarized targets for experimental Halls A, B, and C, spectrometer systems,

	FY 1999	FY 2000	FY 2001
	(dollars in thousands)		
complete a major upgrade of the data reduction system to handle massive amounts of raw data, and to continue fabrication of second generation experiments..................	23,918	24,110	24,325
Total, TJNAF Operations	65,418	66,515	68,400

Bates Operations

Funding is provided to support accelerator operations at the MIT/Bates Linear Accelerator Center.

- Bates will operate 2000 hours in FY 2001, to carry out a program of research and for commissioning activities for the BLAST detector. The laboratory will complete fabrication of the new BLAST detector, that will observe collisions in thin gas targets located on the South Hall Pulse Stretcher Ring. When the scientific program of BLAST commences at the end of FY 2001, the Bates research effort will concentrate on this new experimental facility. Upon completion of the BLAST research program in FY 2004, the Bates facility will begin a 2-year phaseout with operating funding reaching a D&D level of $2,500,000 in FY 2006. The total D&D cost and schedule will be determined at that time.

	(hours of beam)		
	FY 1999	FY 2000	FY 2001
Bates	1000	2000	2000

- Accelerator operations in FY 2001 are providing beams for research programs in the South Hall utilizing the OOPS spectrometers, for testing of internal, polarized, continuous beams in the South Hall Ring, and for development of extracted continuous beams for delivery to the existing South Hall spectrometers.
- AIP funding supports additions and modifications to the accelerator facilities; GPP funding supports minor new construction and utility systems. ....

	FY 1999	FY 2000	FY 2001
new construction and utility systems	13,500	10,885	12,775

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Other Operations			
Funding is provided to support accelerator operations at other facilities.			
▸ Funding is provided for 600 hours of beam, to carry out a limited program of high priority experiments at the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory including an important study of hypernuclei for which the Japanese made a major investment in detector fabrication.	0	0	1,500
Total, Operations	78,918	77,400	82,675
Total, Medium Energy Nuclear Physics	115,695	118,850	125,405

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Research	
▪ **University Research**	
▸ The MIT/Bates research activity decrease reflects the funding profile of BLAST detector system.	-300
▸ Increase reflects effort to increase support for university scientists involved in research at TJNAF	+823
Total, University Research	+523
▪ **National Laboratory Research**	
▸ TJNAF research is increased to partially maintain level of effort.	+120
▸ Other National Laboratory research is increased to enhance the BNL Medium Energy Group's efforts in the RHIC Spin program, and to support National Laboratory scientists carrying out research at TJNAF.	+349
Total, National Laboratory Research	+469
▪ **Other Research**	
▸ Estimated SBIR/STTR and other obligations increase	+288
Total Research	+1,280

	FY 2001 vs. FY 2000 ($000)
Operations	
▪ **TJNAF Operations**	
‣ Funding for the Thomas Jefferson National Accelerator Facility allows accelerator operations to keep pace with inflation.	+1,670
‣ TJNAF experimental support funding nearly maintains level of effort.	+215
Total, TJNAF Operations	+1,885
▪ **Bates Operations**	
‣ MIT/Bates Linear Accelerator Center operations are being supported to complete a program of research with the Out-of-Plane (OOPS spectrometer system) and to develop the capabilities needed for the research program of the BLAST detector. When the BLAST detector is finished, the research effort will focus on this new detector facility.	+1,890
▪ **Other Operations**	
‣ A limited program of high priority experiments is being supported at the Brookhaven AGS commencing in FY 2001 including an important study of hypernuclei for which the Japanese made a major investment in detector fabrication.	+1,500
Total, Operations	+5,275
Total Funding Change, Medium Energy Nuclear Physics	+6,555

Heavy Ion Nuclear Physics

Mission Supporting Goals and Objectives

The Heavy Ion Nuclear Physics subprogram supports research directed at understanding the properties of atomic nuclei and nuclear matter over the wide range of conditions created in nucleus-nucleus collisions. Using beams of accelerated heavy ions at low bombarding energies, research is focused on the study of the structure of nuclei that are only gently excited (cool nuclear matter), but taken to their limits of energy, deformation, and isotopic stability. Such studies, as well as those directed at measuring nuclear reaction processes are important in understanding the production of the elements in stellar burning and supernovae. At much higher relativistic bombarding energies, the properties of hot, dense nuclear matter are studied with the goal of observing the deconfinement of normal matter into a form of matter, a quark-gluon plasma, which is believed to have existed in the early phase of the universe, a millionth of a second after the Big Bang.

Scientists and students at universities and national laboratories are funded to carry out this research at Department of Energy (DOE) supported facilities, as well as at National Science Foundation (NSF) and foreign supported accelerator facilities. The Heavy Ion Nuclear Physics subprogram supports and maintains accelerator facilities located at two universities (Texas A&M and Yale) and three National Laboratories (Argonne, Brookhaven and Lawrence Berkeley) for these studies. The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory, with initial production operation in FY 2000, is a unique world-class facility that addresses fundamental questions about the nature of nuclear matter. At the low-energy heavy ion national facilities (ANL-ATLAS and LBNL-88" Cyclotron) an expanded program of R&D and preconceptual design activities will be undertaken in support of a next generation low-energy facility, the Rare Isotope Accelerator (RIA). All the National Laboratory facilities are utilized by DOE, NSF and foreign supported researchers whose experiments undergo peer review prior to approval for beam time. Capital equipment funds are provided for detector systems, for data acquisition and analysis systems and for accelerator instrumentation for effective utilization of all the national accelerator facilities operated by this subprogram. Accelerator Improvement Project (AIP) funds are provided for additions, modifications, and improvements to the research accelerators and ancillary experimental facilities to maintain and improve the reliability and efficiency of operations, and to provide new experimental capabilities. The Heavy Ion Nuclear Physics subprogram also provides General Purpose Equipment (GPE) and General Plant Project (GPP) funds to Brookhaven National Laboratory (BNL) as part of Nuclear Physics' landlord responsibilities for this laboratory. These funds are for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems. In FY 2001, responsibility for BNL waste management activities has been transferred from the DOE Environmental Management Program (EM) to the Nuclear Physics program.

Funding Schedule

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Research					
University Research	17,507	17,426	17,973	+547	+3.1%
National Laboratory Research	36,146	33,595	33,330	-265	-0.8%
Other Research	375[a]	2,826	2,960	+134	+4.7%
Subtotal, Research	54,028	53,847	54,263	+416	+0.8%
Operations					
RHIC Operations	74,870	102,480	108,210	+5,730	+5.6%
National Laboratory Facility	12,557	13,023	13,090	+67	+0.5%
Other Operations	5,450	10,060	10,840	+780	+7.8%
BNL Waste Management	0	0	5,957	+5,957	+100.0%
Subtotal, Operations	92,877	125,563	138,097	+12,534	+10.0%
Total, Heavy Ion Nuclear Physics	146,905	179,410	192,360	+12,950	+7.2%

Detailed Program Justifications

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001

Research

University Research

Support is provided for the research of scientists and students at 33 universities in 21 states.

- Research using relativistic heavy ion beams, involving about two-thirds of the university scientists supported by the Heavy Ion program, is focused on the study of the production and properties of hot, dense nuclear matter at initial experiments at RHIC where an entirely new regime of nuclear matter now becomes available to study for the first time. University researchers are involved in all aspects of the four RHIC detectors; STAR, PHENIX, BRAHMS, and PHOBOS.
- Research using low energy heavy ion beams, involving about a third of the university scientists, is focused on the study of the structure of nuclei with priorities on studies of highly excited nuclear systems, properties of unstable nuclear systems near the limits where protons and neutrons become unbound, and reactions involving unstable nuclei that are of particular importance in nuclear astrophysics. These studies utilize specialized instrumentation at the ANL-ATLAS and

[a] Excludes $2,100,000 which has been transferred to the SBIR program.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
LBNL-88-inch Cyclotron facilities. Complementary studies are carried out using smaller university facilities (Yale and Texas A&M) whose in-house research programs focus on speciality areas of study and provide an emphasis on student training.	17,507	17,426	17,973
National Laboratory Research			
Support is provided for the research programs of scientists at six National Laboratories (ANL, BNL, LBNL, LANL, LLNL and ORNL).			
▪ **BNL RHIC Research:** BNL scientists play a major role in planning and carrying out research with the four detectors (STAR, PHENIX, BRAHMS and PHOBOS) at RHIC and have major responsibilities for maintaining, improving and developing this instrumentation for use by the user community. FY 2001 will be a critical year as all four RHIC detectors reach their full potential for studies of the expected new forms of nuclear matter that will be created in the heavy ion collisions. The priority for the capital equipment included in this funding is on additional experimental equipment for RHIC, (see Major Items of Equipment) primarily for the Electromagnetic Calorimeter enhancement for STAR and for muon instrumentation for PHENIX.	18,055	13,252	11,275
▪ **Other National Laboratory Research:** ANL (ATLAS) and LBNL (88-inch Cyclotron) scientists have major responsibilities for maintaining, improving and developing instrumentation for use by the user communities at their facilities, as well as playing important roles in carrying out research that addresses the program's priorities. Activities will be focused on studies of the properties of nuclei far from stability using specialized instrumentation, studies of nuclear structure with Gammasphere and support of a new Rare Isotope Accelerator (RIA) facility including R&D and preconceptual design. FY 2001 funding of $3,100,000 is provided for RIA activities. Researchers at LANL, LBNL, and ORNL will utilize their laboratory competencies in undertaking the development of and data analysis from RHIC detectors (e.g., STAR and PHENIX) and will play leadership roles in carrying out research utilizing them. The priorities for funding in research will be the RHIC program, and R&D and preconceptual design activities for a proposed Rare Isotope Accelerator (RIA).	18,091	20,343	22,055
Total, National Laboratory Research	36,146	33,595	33,330

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Other Research			
▪ In FY 1999 $2,100,000 was transferred to the SBIR program. Amounts include the estimated requirements for the continuation of the FY 2000 and FY 2001 SBIR and STTR programs and other established obligations.	375	2,826	2,960
Total, Heavy Ion Nuclear Physics Research	54,028	53,847	54,263

Operations

RHIC Operations

- The Relativistic Heavy Ion Collider (RHIC) will initiate data taking operations during FY 2000 and is anticipated to reach nearly full data production capabilities by the end of FY 2001. RHIC is a unique facility whose colliding relativistic heavy ion beams will permit exploration of hot, dense nuclear matter and recreate the transition from quarks to nucleons that characterized the early evolution of the universe. Studies with colliding heavy ion beams will provide researchers with their first laboratory opportunity to explore this new regime of nuclear matter and nuclear interactions that up to now has only been studied theoretically.

	FY 1999	FY 2000	FY 2001
‣ **RHIC Accelerator Operations:** Support is provided for the operation, maintenance, improvement and enhancement of the RHIC accelerator complex. The RHIC complex includes the Tandem, Booster and AGS accelerators that together serve as the injector for RHIC and that individually or in combination have additional capabilities for providing beams for research. In FY 2001 RHIC will operate with a 4800 hour running schedule. About 1600 hours of this schedule is anticipated to be used for beam studies and to commission operations with polarized protons.	66,800	75,170	78,885

RHIC Operations

	(hours of beam)		
	FY 1999	FY 2000	FY 2001
Research	0	1330	3200
Beam Studies	500	2720	1600
Total	500	4050	4800

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
‣ **RHIC Experimental Support:** Support is provided for the operation, maintenance, improvement and enhancement of the RHIC experimental complex, including detectors, experimental halls, computing center and support for users. RHIC detectors (STAR, PHENIX, BRAHMS and PHOBOS) will reach their initial planned potential in FY 2001. Approximately 950 scientists and students from 90 institutions and 19 countries will participate in the research programs of these four detectors.	8,070	27,310	29,325
Total, RHIC Operations	74,870	102,480	108,210

- **National Laboratory Facility Operations**

Support is provided for two National User Facilities: the ATLAS facility at ANL and the 88-inch Cyclotron facility at LBNL for studies of nuclear reactions, structure and fundamental interactions.

- ‣ Support is provided for the operation, maintenance, improvement and enhancement of the ATLAS and 88-inch Cyclotron accelerator facilities. FY 2001 operations (and beam hours shown below) reflect emphasis on the complementary Gammasphere program at the 88-inch Cyclotron and the development of radioactive beam capabilities at ATLAS. A vigorous program in search of new elements near the recently discovered elements (Z=116 and 118) will be pursued.

	(hours of beam)		
	FY 1999	FY 2000	FY 2001
Total beam hours (ATLAS/88-inch Cyclotron)	10200	10200	10350

‣ In FY 2001 these low-energy facilities will carry out about 70 experiments conducted by about 400 researchers. Accelerator Improvement Project (AIP) funds and capital equipment are provided for the maintenance and upgrade of these facilities and their research capabilities.	12,557	13,023	13,090

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
▪ **Other Operations:** As Landlord for Brookhaven National Laboratory (BNL), the Nuclear Physics program provides GPP funding for minor new construction, other capital alterations and additions, and for buildings and utility systems. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and in meeting its requirement for safe and reliable facilities operation. Since it is difficult to detail these types of projects in advance, a continuing evaluation of requirements and priorities may result in additions, deletions, and changes in the currently planned projects. The total estimated cost of each project will not exceed $5,000,000. In addition, the program has Landlord responsibility for providing General Purpose Equipment (GPE) at BNL.			
▪ At Brookhaven National Laboratory, modifications to the Booster Synchrotron (part of the RHIC complex) and development of a beam line are underway to provide beams for studies of radiation effects on biological and electronic systems in space. This Booster Applications Facility (BAF) is funded by NASA under a work-for-others agreement at no cost to the Nuclear Physics program.	5,450	10,060	10,840
▪ **BNL Waste Management:** Funding is provided in support of activities related to the packaging, shipment, and disposition of hazardous, radioactive or mixed waste generated in the course of normal operations at Brookhaven National Laboratory.	0	0	5,957
Total, Operations	92,877	125,563	138,097
Total, Heavy Ion Nuclear Physics	146,905	179,410	192,360

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Research	
▪ **University Research**	
‣ FY 2001 funding for University Research provides for a constant level of effort compared to FY 2000 for research and educational activities. Priority in the program will be given to research using RHIC and with exotic nuclei far from stability.	+547
▪ **National Laboratory Research**	
‣ Research funding for RHIC, including capital equipment for detectors, is reduced by about $2,000,000 relative to FY 2000 as several Major Items of Equipment are completed. In FY 2001 there will be an increase of $1,500,000 in funding allocated to R&D and preconceptual design activities for the Rare Isotope Accelerator (RIA) project, bringing the total effort in this subprogram to $3,100,000. (An additional $400,000 for RIA R&D and design activities is provided in the Low Energy subprogram where needed expertise resides.) Other research efforts at the National Laboratories are reduced somewhat and will be focused towards the priority areas of the program.	-265
▪ **Other Research**	
‣ Estimated funding for SBIR and other obligations increase from FY 2000.	+134
Total, Research	+416
Operations	
▪ **RHIC Operations**	
‣ FY 2001 funding provides for an estimated 4800 hours running schedule (3200 hours for research), compared to 4050 hours (1330 hours for research) in FY 2000. Capital Equipment and AIP funding are provided at levels approaching what was recommended as appropriate in the RHIC Operations Review carried out by NSAC.	+5,730
▪ **National Laboratory Facility Operations**	
‣ In FY 2001, funding for operations of ATLAS and the 88-Inch Cyclotron is increased by about 4% compared with FY 2000, resulting in an increase in beam hours. Capital Equipment and AIP funding are decreased by approximately the same percentage.	+67
▪ **Other Operations**	
‣ FY 2001 GPP for Brookhaven National Laboratory is increased to support projects that will enhance the usefulness of aging facilities.	+780

	FY 2001 vs. FY 2000 ($000)
▪ **BNL Waste Management**	
▸ As part of the landlord responsibilities for Brookhaven National Laboratory the program assumes responsibility for the waste treatment program previously budgeted for by Environmental Management	+5,957
Total, Operations	+12,534
Total Funding Change, Heavy Ion Nuclear Physics	+12,950

Low Energy Nuclear Physics

Mission Supporting Goals and Objectives

The Low Energy Nuclear Physics subprogram supports research directed at understanding the structure of nuclei, nuclear reaction mechanisms, and experimental tests of fundamental symmetries. At the present time, emphasis is placed on addressing issues in nuclear astrophysics. This research is generally conducted using beams provided by accelerator facilities operated by this subprogram, other Department of Energy programs, or at other domestic or foreign facilities. The Low Energy Nuclear Physics subprogram supports the operation of the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory. University-based research is an important feature of the Low Energy subprogram. Since most of the required facilities are relatively small, they are appropriate for siting on university campuses, where they provide unique opportunities for hands-on training of nuclear experimentalists who are so important to the future of this field. Many of these scientists, after obtaining their Ph.D.s, contribute to a wide variety of nuclear technology programs of interest to the DOE. Part of this work can often be accomplished without the use of accelerators. The study of neutrinos from the sun, whose rate of production is not understood, is an example. Included in this subprogram are the activities that are aimed at providing information services on critical nuclear data and have as a goal the compilation and dissemination of an accurate and complete nuclear data information base that is readily accessible and user oriented. In FY 2001, funding will be provided for an expanded program of R&D and preconceptual design activities in support of an advanced Rare Isotope Accelerator (RIA) facility (partially funded in Heavy Ion Nuclear Physics subprogram).

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
University Research	9,895	9,727	10,475	+748	+7.7%
National Laboratory Research	8,038	9,086	8,360	-726	-8.0%
Nuclear Data	4,775	4,880	5,050	+170	+3.5%
Other	290[a]	1,145	965	-180	-15.7%
RIB Operations	9,310	8,941	9,120	+179	+2.0%
Total, Low Energy Nuclear Physics	32,308	33,779	33,970	+191	+0.6%

[a] Excludes $810,000 which has been transferred to the SBIR program.

Detailed Program Justifications

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
University Research			
▪ The three main components of research at universities in this subprogram are nuclear astrophysics, fundamental interactions in nuclei, and the structure of nuclei.			
▪ Two university accelerators are supported in Low Energy: the University of Washington, Nuclear Physics Laboratory (NPL), and the Triangle Universities Nuclear Laboratory (TUNL) facility at Duke University. These small university facilities fit within the low energy program by providing a source of light ion beams. Long term measurements of a detailed nature are possible at these dedicated facilities and they are used to make measurements that address questions of a fundamental physics nature.			
▪ University scientists perform research at on-site facilities, as user groups at National Laboratory facilities, and at the Sudbury Neutrino Observatory (SNO). These activities address a broad range of fundamental issues as diverse as properties of nuclei, the nature of the weak-interaction and the production mechanisms of chemical elements in stars and supernovae	9,895	9,727	10,475
National Laboratory Research			
▪ **Radioactive Ion Beam Facility Research:**			
‣ The RIB facility focuses mainly on nuclear astrophysics problems bearing on the creation of the elements and on the properties of nuclei with extreme proton/neutron ratios.			
‣ The Daresbury Recoil Separator, a $2,000,000 device contributed by the United Kingdom, is being utilized to separate the products of interest from particle backgrounds that are a trillion times more intense, enabling the measurement of the important nuclear reactions that fuel the explosion of stars.			
‣ Capital equipment funds are provided to develop new beam species and for research instrumentation.			
‣ Research and Development (R&D) activities leading to an advanced Rare Isotope Accelerator (RIA) will continue	4,808	4,254	4,985

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
▪ **Other National Laboratory Research:**			
‣ In a major effort to study the processes that control our sun, the Sudbury Neutrino Observatory (SNO) was created. This observatory consists of a 40 foot diameter plastic (acrylic) vessel holding 1,000 tons of heavy water that is the solar neutrino detector. SNO is located 6,800 feet underground. The detector water fill was completed in FY 1999 and data taking has started. The level of SNO support at the national laboratories is at a level of effort that allows for efficient collection and analysis of data.			
‣ The SNO detector, whose first results are expected in FY 2001, addresses the question of whether the observed dearth of solar neutrinos results from unexpected properties of the sun, or whether it results from a fundamental property of neutrinos-namely that neutrinos produced in radioactive decay in the sun change their nature during the time it takes them to reach the earth. This latter explanation would imply that the neutrinos have mass.			
‣ Funds are also provided for R&D and preconceptual design activities directed at the development of an advanced Rare Isotope Accelerator (RIA).	3,230	4,832	3,375
Total, National Laboratory Research	8,038	9,086	8,360

Nuclear Data

- This is a service function of the Nuclear Physics program that collects, evaluates, stores, and disseminates information on nuclear properties and reaction processes for the community and the nation. The focal point for its national and international activities is at the DOE managed National Nuclear Data Center (NNDC) at Brookhaven National Laboratory.
- The NNDC relies on a network of individual nuclear data professionals located in universities and at other national laboratories who assist in assessing data as well as developing new novel, user friendly electronic network capabilities.
- The U.S. Nuclear Data Network (USNDN), a collaboration of DOE supported nuclear data

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
scientists, reports to and supports the NNDC in data evaluation and development of on-line access capabilities	4,775	4,880	5,050

Other

- In FY 1999 $810,000 was transferred to the SBIR program. The FY 2000 and FY 2001 amounts include the estimated requirement for the continuation of the FY 2000 and FY 2001 SBIR and STTR programs and other established obligations. The Lawrence and Fermi Awards that are funded under this line, provide annual monetary awards to honorees selected by the Department of Energy for their outstanding contributions to nuclear science. .... 290 | 1,145 | 965

RIB Operations

- The RIB facility is planned to provide beam hours for research as indicated below:

	(hours of beam)		
	FY 1999	FY 2000	FY 2001
RIB	2400	2400	2300

- The RIB facility is a technically difficult project, that couples the existing cyclotron and tandem accelerators. Becoming fully operational in FY 1998, it is now routinely providing radioactive ion beams of arsenic, fluorine and Nickel-56 for a user community of over 200 researchers.
- Research at the Oak Ridge Electron Linear Accelerator (ORELA), that is also operated by RIB staff, is aimed at resolving discrepancies in the rate of production of primordial elements compared with theoretical predictions, such as models that predict the formation of heavy elements like carbon, nitrogen, and oxygen in the Big Bang. .... 9,310 | 8,941 | 9,120

	FY 1999	FY 2000	FY 2001
Total, Low Energy Nuclear Physics	32,308	33,779	33,970

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
University Research	
FY 2001 funding provides constant effort support for research, and additional capital equipment support for new initiatives in neutrino related research, such as the KamLAND experiment, and nuclear astrophysics related projects.	+748
National Laboratory Research	
Research support is reduced compared to FY 2000 with high priority on nuclear astrophysics studies and involvement in the KamLAND experiment. Support at the level of $400,000 continues for R&D and preconceptual design activities for a next generation Rare Isotope Accelerator (RIA). Capital equipment investments for activities in National Laboratory Research are reduced due to completion of SNO related projects.	-726
Nuclear Data	
Funding provides a limited increase in operating costs for the nuclear data facilities and a new initiative in nuclear astrophysics data services.	+170
Other	
Estimated FY 2001 funds for SBIR decrease compared to FY 2000	-180
RIB Operations	
Operations are funded at slightly less than a constant effort than in FY 2000.	+179
Total Funding Change, Low Energy Nuclear Physics	+191

Nuclear Theory

Mission Supporting Goals and Objectives

Theoretical Nuclear Physics is a program of fundamental scientific research that provides new insight into the observed behavior of atomic nuclei. From continuing interactions with experimentalists and experimental data, solvable mathematical models are developed which describe observed nuclear properties, and the predictions of the models are tested with further experiments. From this process evolves a deeper understanding of the nucleus. Traditionally, there are two generic types of nuclear models: (1) microscopic models where the nucleus is viewed as a system of interacting discrete protons and neutrons, and (2) collective models where the nucleus is treated as a drop of fluid. With the establishment of the Quantum Chromodynamics and the standard model, the ultimate goal of nuclear theory now is to understand nuclear models, and hence nuclei, in terms of quarks and gluons. An area of increasing interest recently is in nuclear astrophysics-topics such as supernova explosions, nucleosynthesis of the elements, and the properties of neutrinos from the sun.

The Nuclear Theory program supports all areas of nuclear physics, and is carried out at universities and National Laboratories. Some of the investigations depend crucially on access to forefront computing, and to the development of efficient algorithms to use these forefront devices. Components of the program are selected primarily on the basis of peer review by internationally recognized experts. A very significant component of the program is the Institute for Nuclear Theory (INT), where there is an ongoing series of special topic programs and workshops which include experimentalists. The Institute is a seedbed for new collaborations, ideas, and directions in nuclear physics.

The program is greatly enhanced through interactions with complementary programs overseas and those supported by the National Science Foundation. Many foreign theorists participate on advisory groups and as peer reviewers. There is large participation in the INT by researchers from Europe and Japan.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
University Research	10,363	10,113	10,535	+422	+4.2%
National Laboratory Research	5,277	5,562	7,620	+2,058	+37.0%
Total, Nuclear Theory	15,640	15,675	18,155	+2,480	+15.8%

Detailed Program Justifications

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
University Research			
▪ Research is conducted through individual grants to researchers at roughly 40 universities. ▪ The range of topics studied through these grants is broad, and each of the active areas of experimental nuclear physics is supported by nuclear theory activities. ▪ The overall character of the research program evolves with time to reflect changes in the overall nuclear physics program through redirecting some individual programs, phasing out other programs and starting new programs. ▪ Almost 100 Ph.D. students are supported by the Theory program; a major source of new Ph.D.s in nuclear physics in this country. ▪ The level of effort in this activity has been essentially constant in recent years. The bulk of the funds provided are used for salary support for faculty, postdocs, and students doing thesis research. Thus, a constant level of effort depends on a cost-of-living increase. ▪ The number of nuclear theorists supported in this activity is consistent with the recommendations for manpower levels in the report of the DOE/NSF Nuclear Science Advisory Committee Subcommittee on Nuclear Theory-1988.	10,363	10,113	10,535
National Laboratory Research			
▪ Funding provides for new activities to model and calculate complex astrophysical nuclear processes, for example, in stellar supernovae explosions, and the quark/gluon-based structure of nuclei using "lattice gauge" techniques. Both efforts require investments in new computational modeling and simulation research and show great promise in pushing our understanding of the physics of these processes to new levels. ▪ Through this activity, theoretical nuclear physics groups are supported at 6 National Laboratories. ▪ The range of topics in these programs is broad, and each of the active areas of experimental nuclear physics is supported by at least some of these nuclear theory activities.			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
▪ In all cases, the nuclear theory research at a given laboratory provides support to the experimental programs at the laboratory, or takes advantage of some unique facilities/programs at that laboratory.			
▪ The larger size and diversity of the National Laboratory groups make them particularly good sites for the training of nuclear theory postdocs.			
▪ The level of effort in this activity has been essentially constant in recent years. The bulk of the funds provided are used for salary support for staff. Thus, a constant level of effort depends on a cost-of-living increase.			
▪ The number of nuclear theorists supported in this activity is consistent with the recommendations for manpower levels in the report of the DOE/NSF Nuclear Science Advisory Committee Subcommittee on Nuclear Theory-1988.	5,277	5,562	7,620
Total, Nuclear Theory	15,640	15,675	18,155

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
▪ **University Research**	
‣ Funding level reflects an increased level of support for the university grants program.	+422
▪ **National Laboratory Research**	
‣ Funding provides for new efforts which require investments in computational modeling and simulation activities which show great promise for pushing our understanding of the physics to new levels. These activities will model and calculate complex astrophysical nuclear processes, for example, in stellar supernovae explosions, and the quark/gluon based structure of nuclei using "lattice gauge" techniques.	+2,058
Total Funding Change, Nuclear Theory	+2,480

Capital Operating Expense and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
General Plant Projects	4,000	5,855	6,735	+880	+15.0%
Accelerator Improvement Projects	5,520	4,400	5,500	+1,100	+25.0%
Capital Equipment...................................	30,070	30,880	34,155	+3,275	+10.6%
Total, Capital Operating Expenses	39,590	41,135	46,390	+5,255	+12.8%

Major Items of Equipment *(TEC $2 million or greater)*

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1999	FY 2000	FY 2001	Accept-ance Date
STAR Silicon Vertex Tracker.................	7,000	4,950	1,300	750	0	FY 2000
PHENIX Muon Arm Instrumentation.......	12,900	5,975	2,635	2,525	800	FY 2002
Analysis System for RHIC Detectors	7,900	2,775	3,600	1,525	0	FY 2000
BLAST Large Acceptance Detector........	5,200	900	1,600	1,500	1,200	FY 2001
STAR EM Calorimeter...........................	8,600	0	0	1,800	2,800	TBD
G0 Experiment Detector [a]......................	3,387	400	1,064	1,004	874	FY 2002
Total, Major Items of Equipment............		15,000	10,199	9,104	5,674	

[a] The G0 Experiment Detector at TJNAF began as an NSF project with a small contribution of DOE funds (below MIE threshold). Subsequently, the cost estimate for the detector increased, leading to increased DOE and NSF contributions. The DOE contribution was raised above the MIE threshold. Therefore a MIE has been identified in the FY 2001 budget. The NSF contribution to this effort in actual year dollars is $3,605,000.

Biological and Environmental Research

Program Mission

For over 50 years the Biological and Environmental Research (BER) has been investing to advance environmental and biomedical knowledge connected to energy. The program provides fundamental science to underpin the business thrusts of the Department's strategic plan. Through its support of peer-reviewed research at national laboratories, universities, and private institutions, the program develops the knowledge needed to identify, understand, anticipate, and mitigate the long-term health and environmental consequences of energy production, development, and use. The research is also designed to provide science in support of the Energy Policy Act of 1992.

The high quality of the research in this program is continuously evaluated through the use of merit based peer review and scientific advisory committees.

Program Goal

To develop the information, scientific "know-how," and technology for identification, characterization, prediction, and mitigation of adverse health and environmental consequences of energy production, development, and use.

Program Objectives

- *To Contribute to a Healthy Citizenry* - Map the fine structure of the human genome by 2003, thus providing resources to the international research community needed to identify disease genes and develop broad diagnostic and therapeutic strategies, including the development of individual risk assessments; conduct fundamental research necessary for the development of advanced medical technologies and radiopharmaceuticals; and use the unique National Laboratory facilities to determine biological structure and function at the molecular and cellular level in support of the Nation's biomedical sciences, pharmaceutical interests, and environmental activities.
- *To Contribute to Cleanup of the Environment* - Conduct fundamental research necessary for the development of advanced remediation tools for containing wastes and cleaning up DOE's contaminated sites, particularly in support of the mission of DOE's Environmental Management (EM) office.
- *To Understand and Adapt to Global Environmental Change* - Conduct fundamental research to acquire the data and develop the understanding necessary to predict how energy production and use can affect the global and regional environment and to foster technologies that can help us mitigate and adapt to global environmental change.

Performance Measures

The quality and appropriateness of the Biological and Environmental Research (BER) program and its individual research projects are judged by rigorous peer reviews conducted by internationally recognized scientific experts using criteria such as scientific merit, appropriateness of the proposed approach, and qualifications of the principal investigator. Highest quality research is maintained by taking appropriate and, if needed, corrective management actions based on results of the reviews. A measure of the quality of the research is the sustained achievement in advancing knowledge as indicated by the publication of research results in refereed scientific journals, by invited participation at national and international scientific conferences and workshops, and by honors received by BER-supported researchers. Progress in the field is also regularly compared to the scientific priorities recommended by the Biological and Environmental Research Advisory Committee (BERAC) and the National Science and Technology Council's (NSTC) committees on Environment and Natural Resources and on Fundamental Science.

An overarching and unique performance measure of the BER program is the diversity of program reviews conducted. This is particularly the case for BER program elements that are components of international research endeavors, e.g., the International Human Genome Project and the Global Change Research Program. In addition to panel reviews that evaluate and select individual projects and programmatic reviews by the chartered BERAC, these program elements are evaluated by interagency (and international) review bodies and by Boards and Committees of the National Academy of Sciences.

The BER program goes one step further in soliciting program reviews. Panels of distinguished scientists are charged with evaluating the quality of individual programs and with exploring ways of entraining new ideas and research performers from different scientific fields. This strategy is based on the conviction that the most important scientific advances of the new century will occur at the interfaces between scientific disciplines such as biology and information science. Groups like JASON and The Washington Advisory Group (TWAG), involving physicists, mathematicians, engineers, etc., are among the organizations that have studied BER program elements such as the Atmospheric Radiation Measurement (ARM) program, climate change prediction activities, the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), and the Human Genome program.

Facility operations are also monitored by peer reviews and user feedback. These facilities are provided in a manner that meets user requirements (as indicated by achieving performance specifications while protecting the safety of the workers and the environment); facilities are operated reliably and according to planned schedules; and facilities are maintained and improved.

Specific BER program performance measures are:

Biological and Environmental Research

- Excellence in basic research: All research projects will continue to be reviewed by appropriate peers and selected through a merit-based competitive process.

Life Sciences

- Structural Biology: Commission the neutron protein crystallography station at the Los Alamos Neutron Science Center (LANSCE).
- Microbial Genomics/Climate Change Technology Initiative: Complete the genetic sequencing of at least two additional microbes that produce methane or hydrogen from carbonaceous sources or that could be used to sequester carbon.
- Low Dose Radiation Research: Convene second Low Dose Radiation Research program meeting with broad participation from program investigators, other Federal agencies, regulators, interested community representatives, and Congress.
- Closing in on the final Human DNA sequence: Initiate the “finishing” of the high quality DNA sequence of human chromosomes 5, 16, and 19 to international “Bermuda” standards. Finished

sequence will include the vast majority of regions of greatest biological interest on these chromosomes but will not include the most difficult to sequence regions at the ends (telomeres) and middle (centromere) of each chromosome.

- By the end of FY 2001, the DOE Joint Genome Institute (JGI) will complete the sequencing and submission to public databases of 100 million finished and 250 million high quality draft base pairs of DNA, including both human and mouse.
- Sixty percent of the newly discovered biological structures published in the peer reviewed literature will result from data generated at synchrotron user stations served by the BER structural biology facilities program.
- A new research program, the Microbial Cell Project, will be initiated to develop a comprehensive understanding of the complete workings of a microbial cell, from the DNA sequence to the complex interaction of the genes and proteins in a cell that give the microbe its life and its unique characteristics and behaviors.
- The development and upgrade of scientific facilities (including experimental stations) will be kept on schedule and within cost.
- The operating time lost at scientific user facilities due to unscheduled downtime will be less than 10 percent of the total scheduled possible operating time, on average.
- Independent assessments will judge BER research programs to have high scientific quality.
- Exploratory research will be initiated to develop new technologies to image gene action in humans to understand how genes function in health and disease, and for monitoring gene therapy treatments.

Environmental Processes

- Work will proceed on the development and testing of the next generation coupled ocean-atmosphere-sea ice climate model, leading to better information for assessing climate change and variability at regional, rather than global scales. New and better numerical techniques and physical parameterizations of physical processes in component General Circulation Models (GCMs) will be developed, and existing methods used in atmospheric, ocean, and sea ice GCMs will be improved.
- Model-model and model-data intercomparisons of long-term climate simulations generated with coupled ocean-atmosphere GCMs will be completed. Performance of the coupled GCMs will be measured by their ability to simulate the observed seasonal cycle amplitude in near surface temperature and seasonal patterns in amounts of precipitation. Furthermore, analyses will identify potential causes for inter-model differences in their ability to simulate observed long-term patterns in both the mean state and the variation in climate at regional and global scales.
- Five Intensive Operations Periods (IOPs) will be conducted on schedule at the Atmospheric Radiation Measurement (ARM) Southern Great Plains site. Data will be obtained from the second station on the North Slope of Alaska as planned. The third station in the Tropical Western Pacific, on Christmas Island, will become operational on schedule and within budget in accordance with the program plan.
- ARM research will support about 50 principal investigators working on cloud physics and on solar and infrared radiation interactions with water vapor and aerosols. More than 75 peer reviewed

papers and twice that number of conference papers will be published. The ARM Science Team will be realigned to bring more emphasis on use of ARM observations to develop parameterizations and approaches to improve atmospheric general circulation models. Additional field studies will be conducted, focusing on the connections of ARM data with carbon cycle processes.

- AmeriFlux Sites: Intersite comparisons will be conducted of net annual carbon sequestration for twenty-five AmeriFlux sites representing major ecosystem types and land uses in North and Central America, including deciduous and coniferous temperate forests, tropical forests, croplands, grasslands, rangelands and tundra ecosystems. Initial intersite analysis completed of the effects of environmental factors such as inter-annual climate variation on the net exchange of carbon and the role of biophysical processes controlling this exchange will help define the current global carbon dioxide budget. Results will also improve predictions of future carbon dioxide concentrations, and enhance understanding of how carbon sequestration by the terrestrial biosphere is affected by climate, pollution, land use, and other factors.
- Results from the six Free-Air Carbon Dioxide Enrichment (FACE) experiments will elucidate the direct effects of elevated atmospheric carbon dioxide levels on the growth, productivity, species interactions, water use efficiency, and carbon sequestration of terrestrial plants.
- Education accomplishments: The Global Change Education program will continue providing support to both undergraduate and graduate students in DOE-related global change research. Over 30 DOE-sponsored students participate in the program, including the DOE Summer Undergraduate Research Experience (SURE), the DOE Graduate Research Environmental Fellowships (GREF), and the NSF Significant Opportunities in Atmospheric Research and Science (SOARS) Program.
- The BER Post Doctoral Fellowship program will continue making 4-10 appointments.
- Carbon Sequestration: Research programs will follow the paths set out in the roadmap document "*Carbon Sequestration Research and Development Report*." Research in enhancing the terrestrial biosphere will focus on increasing carbon fixation by plants, reducing carbon dioxide emissions from soils, and assessing potential adverse and beneficial side effects. Research in ocean sequestration will focus on enhancing the long-term removal of atmospheric carbon dioxide by oceanic microorganisms and injecting carbon dioxide into the deep ocean, with an emphasis on environmental consequences of both.

Environmental Remediation

- The first Field Research Center (FRC) for the Natural and Accelerated Bioremediation Research (NABIR) program will be selected at a DOE site in early calendar year 2000. Field site characterization will be completed and the subsurface research at the FRC will be started during 2001, providing the fundamental knowledge for development of bioremediation methodologies for containment and cleanup of hazardous materials.
- NABIR Scientists will transfer understanding of biogeochemical processes in the subsurface at selected Uranium Mill Tailing Remedial Action (UMTRA) Program sites to the UMTRA Groundwater Project.
- Preliminary quantitative field-scale assessment of the role of natural subsurface heterogeneity in promoting and retarding the transport of injected bacteria will be completed and will help evaluate

the viability and effectiveness of injecting microorganisms for in situ bioremediation of contaminated DOE sites.

- The William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) will be identified and cited in research publications and research proposals by scientists in academia and at National Laboratories as an important and valuable resource for molecular-level environmental sciences research.
- It will be demonstrated that at least 75% of the users of the William R. Wiley Environmental Molecular Sciences Laboratory are satisfied or very satisfied with access to its facilities and equipment.

Medical Applications and Measurement Science

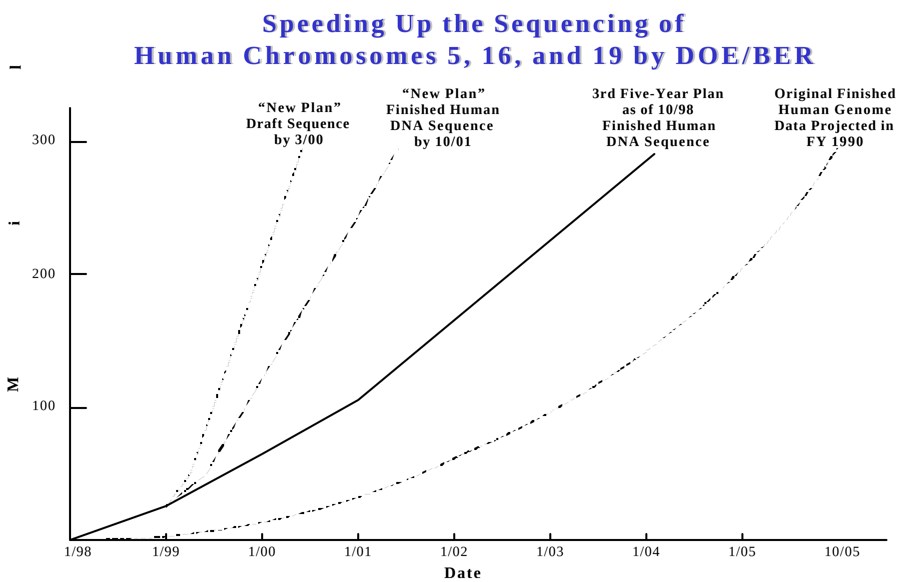
- Progress in Boron Neutron Capture Therapy (BNCT) Research: Phase I clinical trials of BNCT at reactor sources of neutrons will be completed and research on accelerator-based BNCT will be underway. These activities will provide the basis for evaluating the efficacy of BNCT and for designing phase II clinical trials that include reactor and accelerator-based sources of neutrons.
- Biomedical engineering will become a major focus of the Medical Applications program advancing fundamental concepts, creating knowledge from the molecular to the organ systems level, and developing innovative biologics, materials, processes, implants, devices, and informatics systems for the diagnosis, prevention, and treatment of disease.
- The BER Medical Applications program will initiate exploratory research to develop new messenger RNA (mRNA) based radiotracer technologies for imaging gene expression in animals in real time.

Significant Accomplishments and Program Shifts

Life Sciences

- **Warrior Bug Sequenced** - The complete DNA sequence of *Deinococcus radiodurans*, the remarkable radiation- and desiccation-resistant microbe, referred to in the popular press as "Conan the Bacterium**,"** has been determined. The Institute for Genomic Research (TIGR) in Rockville, Maryland has completed sequencing the entire 3 million base pair genome of *D. radiodurans* with funds from the BER microbial genome program. This DNA sequence information should provide additional insights into the astonishing mechanisms for DNA repair in *D. radiodurans* in addition to improving opportunities for engineering *D. radiodurans* into a potential workhorse for helping cleanup DOE waste sites.
- **Warrior Bug Tackles Waste** - *Deinococcus radiodurans*, cannot normally degrade solvents that are part of the mixed wastes at many DOE sites. A team of BER-funded scientists at the Uniformed Services University for the Health Sciences (USUHS) in Bethesda, Maryland have transferred genes from *Pseudomonas putida* into *D. radiodurans* that code for enzymes that degrade toluene and related solvents. The new *D. radiodurans* can degrade toluene and toluene-related solvents. The engineered *Deinococci* could also survive levels of toluene and trichloroethylene that would normally dissolve most other bacteria, suggesting that these engineered microbes might survive in radioactive and solvent containing mixed wastes and degrade the solvents.

- **Genomic Sequencing of a Cleanup Bug** - A microbe considered to be one of the most important for bioremediation, *Shewanella putrefaciens*, has had the complete sequence of its DNA determined. The Institute for Genomic Research (TIGR) in Rockville, Maryland determined the sequence with funding from the BER microbial genome program. *Shewanella* is normally involved in microbially influenced corrosion, anaerobic consumption of toxic organic pollutants and conversion of toxic metals and radionuclides to less chemically toxic forms. Knowing the DNA sequence of this microbe will enable scientists to develop improved bioremediation strategies for cleaning up DOE waste sites.
- **Genomic Sequencing of a "Carbon Manager"** - A microbe considered to be a player in the global carbon cycle, *Chlorobium tepidum*, has had its complete sequence of its DNA determined. The Institute for Genomic Research (TIGR) in Rockville, Maryland determined the sequence with funding from the BER Microbial Genome Program. Having this information is an important first step for developing new strategies to use the microbe to reduce carbon in the atmosphere.
- **A "Which Bugs III" Picks CCT Hit List** - Sixteen leading microbiologists met to help BER pick a list of microbes for genomic DNA sequencing as part of the Climate Change Technology research (CCT) to better understand global carbon utilization. The four microbes that made the final list all participate in "carbon management" processes, particularly carbon sequestration and energy production (e.g., methane and hydrogen production), roles that many microbiologists think are the most important of microbial life on Earth. DNA sequencing of these four microbes is being done at the DOE Joint Genome Institute's Production Sequencing Facility in Walnut Creek, California.
- **One Step Closer to a Complete Human DNA Sequence** - The DOE Joint Genome Institute's Production Sequencing Facility in Walnut Creek, California will complete a working draft of human chromosomes 5, 16, and 19 by March 2000. This is part of BER's contribution to the international effort to sequence the entire human genome by 2003 (NIH and the British Wellcome Trust fund the sequencing of most of the remaining 90 percent). This working draft represents roughly 90 percent of the entire sequence of these three chromosomes completed to 99 percent accuracy. This draft sequence, together with drafts produced by other sequencing centers around the world, will open the floodgates of biological information to scientists and reduces the time and effort needed to complete the entire high quality sequence. BER's effort to complete finished sequence for chromosomes 5, 16, and 19 is scheduled for completion by October 2001.



- **Resources to Speed Sequencing of the Human Genome** - The widely agreed on strategy for sequencing the human genome is based on the use of small pieces of DNA bacterial artificial chromosomes (BACs) that carry fragments of human DNA from known locations throughout the entire human genome. The BER human genome program funded research at The Institute for Genomic Research in Rockville, Maryland and at the University of Washington in Seattle, Washington that provided the sequencing community with a complete set of BAC-based genetic markers. These markers are needed to assemble both the draft and final human DNA sequence.

- **Production Sequencing Facility Open for Business** - The Production Sequencing Facility (PSF) is DOE's principal sequencing facility and is responsible for the Department's contribution of human DNA sequence as part of the international human genome project. Although the PSF's first priority is sequencing human DNA, it is also sequencing microbial DNA, as part of the DOE Climate Change Technology research, and mouse DNA, to take advantage of the wealth of information on mouse biology to better understand the function and control of human genes.

- **Understanding the Health Impacts of Low Dose Radiation** - In FY 1998 BER initiated a new low dose radiation research program that will develop the scientific information needed to make regulatory and cleanup decisions that protect people from the adverse health risks from exposure to radiation. A key question to be addressed by this program is whether there are levels of external radiation that do not cause biological effects greater than those induced by normal cellular processes or background radiation. The program is a collaborative and highly coordinated effort between BER and the Office of Environmental Management. Information resulting from the program is made broadly available to scientists, the public, regulators, and Congress through publications in the peer-reviewed literature and through interactive scientific meetings, web sites, and educational materials. Program information, including a ten year program plan developed by the Biological and Environmental Research Advisory Committee, is available on the web site at http://www. lowdose.com.

- **Human Subjects Research Database on the Web**. The FY 1998 update of the Department's Human Subjects Research Database is available on the World Wide Web at http://www.er.doe.gov/production/ober/humsubj/database.html. The database was begun in response to Congressional interest following the Secretary of Energy Openness Initiative in 1994. The database consists of a detailed description of 258 research projects at 35 research facilities.

- **Review of DOE-Wide Informed Consents and Education Updates**. BER staff have completed a review of informed consents and human subject educational plans for all DOE sites (and the corresponding operations offices) conducting human subjects research. These reviews by DOE, the only agency to conduct this exercise, are conducted every three years to upgrade informed consents and to encourage education on human subject issues across the DOE complex.

- In FY 1999, the performance goal "determine 70 percent of the DNA sequence of 10 additional microbes with potential use in waste cleanup or energy production" was exceeded. The performance goal "discover new biological structures with more than 60 percent of the new biological structures published in the peer-reviewed literature resulting from data generated as part of the structural biology synchrotron user station program" was fully met.

Environmental Processes

- **Massively Parallel Version of the Community Climate Model (CCM3) Developed** - A version of the CCM3 climate model at the National Center for Atmospheric Research was developed and programmed to run on a massively parallel computer to perform coupled climate model experiments. Highly optimized atmosphere, ocean, and sea ice general circulation model codes that run effectively on massively-parallel scientific supercomputers have been completed and tested for use in climate change studies. The Parallel Climate Model (PCM), which more accurately represents the physical ocean, sea ice and atmosphere motion, has been tested on three different parallel supercomputers. This is a significant step in developing the next generation of climate models.

- **Coupled Climate Models More Accurately Simulate Regional Climate Patterns and Changes** - Combining present generation atmospheric and ocean general circulation models into a coupled climate model provides improved simulations of the present climate compared to the climate simulated by uncoupled atmospheric general circulation models alone. Inclusion of increases in carbon dioxide and sulfate aerosols yields regional climate changes similar to observed climate patterns. These results emphasize the need to develop comprehensive, fully coupled climate models and to include in the models those environmental factors that affect the radiative forcing of climate in order to accurately simulate observed patterns of climate variability and change at regional resolution.
- **Surface Heat Budget Data for the Arctic** - The Atmospheric Radiation Measurement (ARM) program provided the atmospheric research component of the multi-agency Surface Heat Budget of the Arctic Ocean (SHEBA) experiment. The SHEBA experiment addressed the interactions among sea ice, atmospheric radiation, and clouds in the Arctic and the corresponding effects on polar and global climate.
- **Looking at Clouds from Both Sides** - The joint ARM-Unmanned Aerial Vehicles and NASA study of tropical cirrus clouds was completed, providing new information on key cloud formations that moderate the radiation budget of the Earth.
- **Unbroken Data Streams** - Three state-of-the-art climate observatories have been continuously operated by the ARM program, with over two hundred instruments at the Southern Great Plains (SGP) site, the tropical western Pacific (TWP) sites at Manus and Nauru and the North Slope of Alaska sites at Barrow and Ataqasuk stations. The SGP is the largest of the three and produces a data stream of radiation and atmospheric column properties unmatched in terms of measurements, completeness, and temporal extent. Continuous operation provides virtually unbroken streams of atmospheric and surface data to climate and atmospheric scientists. Five intensive operational periods (IOPs) were conducted at the Southern Great Plains, one at Nauru and surrounding ocean in the TWP and one around Barrow on the North Slope of Alaska.
- **ARM Supports USDA Campaign** - ARM provided real-time and archive access to the ARM data for the Southern Great Plains (SGP), as well as other operational support for the United States Department of Agriculture SGP99 operation, to develop soil moisture retrieval algorithms for the NASA Advanced Microwave Scanning Radiometer, test the feasibility of soil moisture retrieval from the NASA Microwave Imager, and evaluate multi-frequency, multi-polarization active passive information using a new Jet Propulsion Laboratory aircraft instrument. The other NASA instruments are on satellites.
- **More CO_2 Facts** - Free-Air Carbon Dioxide Enrichment (FACE) experiments provide new and vital information on the response of intact ecosystems to increased atmospheric concentrations of carbon dioxide. Seven long-term experiments produced new data for many physiological and growth parameters of forest, grassland, and crop ecosystems. Initial results show that increased

carbon dioxide caused greater productivity and improved water use efficiency of these systems. A significant part of the productivity increase occurs below ground with roots, soil microflora and the formation of soil organic matter. Results from the loblolly pine FACE experiment, conducted jointly by Duke University, the Brookhaven National Laboratory, the University of Illinois, and other institutions, show that portions of the pine forest exposed for two years to a 60% increase in atmospheric carbon dioxide exhibited a 25% increase in net productivity relative to that for areas of the forest exposed to current levels of atmospheric carbon dioxide. It was estimated that if a similar response occurred globally with other forest ecosystems, the enhanced growth could, in effect, fix about 50% of the excess carbon dioxide produced by human activities by the year 2050.

- **Plant responses to elevated CO_2 influenced by soil nitrogen availability** - A three-year study was completed on the effects of elevated atmospheric carbon dioxide and soil nitrogen availability on the growth of trembling aspen. Results show a 37% increase in the growth of the trees that were both exposed to the elevated carbon dioxide and growing in soils with high nitrogen availability. This 37% increase contrasts with only a 17% growth increase in trees exposed to the same level of carbon dioxide but growing in soils with low nitrogen availability. The results indicate that even trees growing in soils with low nitrogen availability will exhibit an increase in growth with rising atmospheric carbon dioxide levels but the magnitude of the response will be influenced by the amount of available nitrogen and perhaps other essential nutrients in the soil.
- **Data Center Serves the World** - In addition to serving as the international World Data Center for Atmospheric Trace Gases, the Carbon Dioxide Information Analysis Center (CDIAC) serves as the primary global-change data and information analysis center of the U.S. Department of Energy. More than just an archive of data sets and publications, CDIAC enhances the value of its holdings through intensive quality assurance, documentation, and integration. In recognition of this, CDIAC continued to serve as the Quality Systems Science Center for the tri-national North American Research Strategy for Tropospheric Ozone (NARSTO) and the data archive center for the AmeriFlux network of carbon dioxide flux measurement sites.
- **Chemistry of Energy-Related Pollutants -** Major field campaigns were conducted in the areas of Phoenix, Nashville, and Philadelphia to investigate dominant aspects of the chemistry and transport of energy-related pollutants. Analysis of the data continues.
- **Carbon Sequestration Research Begins Under Climate Change Technology Initiative (CCTI)** - The carbon sequestration research program was initiated by funding two multi-institutional, interdisciplinary carbon sequestration research centers. One center focuses on research to enhance carbon sequestration in the terrestrial biosphere and the second on enhancing carbon sequestration in the ocean. Both centers support research to identify and understand the natural processes and environmental and biological factors controlling the sequestration of carbon and how these processes and/or limiting factors can be modified in order to achieve the goal of enhancing the natural sequestration of carbon in both terrestrial and oceanic systems.
- In FY 1999, the following performance goal was exceeded:
  - Initiate a new joint Biological and Environmental Research – Basic Energy Sciences program in fundamental science that will underpin new opportunities and technologies in carbon capture.

Environmental Remediation

- **NABIR Research Initiated at UMTRA (Uranium Mill Tailing Remedial Action) Sites** - Interdisciplinary teams of NABIR researchers have partnered with UMTRA site managers at Shiprock, New Mexico and Gunnison, Colorado, to investigate the potential for naturally-occurring microbes to remove uranium in the aqueous phase, reducing risk to humans and the environment. For example, a small group of NABIR scientists are working closely with environmental restoration staff associated with the Uranium Mill Tailing Remediation Action (UMTRA) Groundwater Project to better characterize subsurface biogeochemical processes at a select number of UMTRA sites. Through this collaboration, both the NABIR Program and the UMTRA Program are able to leverage resources while at the same time meet program objectives.
- **Successful Completion of Interagency Program on Bioavailability of Contaminants -** A three year research program in which DOE partnered with the National Science Foundation, the Environmental Protection Agency and the Office of Naval Research, has led to a new understanding of the mechanisms that control the bioavailability of organic and metallic contaminants in soils and sediments. This knowledge is fostering new approaches to accelerate bioremediation such as through the application of co-solvents to increase bioavailability, as well as new strategies to stabilize contaminants in situ through natural processes such as complexation.
- **EMSL Attracts Large Number and Wide Variety of Users** - In its second year of full operations, the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) attracted over 600 users from academia, government laboratories, and private industry, with over half the users coming from academia.
- **EMSL Establishes Annual Users Meeting and Users Advisory Group** - The EMSL organized and hosted its first annual users meeting and established a users advisory group to help EMSL management understand the needs of the user community. The users meeting provided a forum for presentations and discussions of on-going research in the following areas: environmental chemistry and transport, massively parallel computing in the environmental molecular sciences, physics and chemistry of oxide surfaces, and structural and functional proteomics.
- **NABIR Field Research Sites** - The first Field Research Center for the Natural and Accelerated Bioremediation Research (NABIR) Program has been narrowed to one DOE site pending completion of an Environmental Assessment. This site presents significant opportunities and challenges for long-term basic research on metal and radionuclide contamination in the subsurface. In addition, the NABIR Program is leveraging its resources for field research by coordinating with environmental restoration programs at other DOE sites to allow NABIR scientists to obtain groundwater and sediment samples and conduct in situ research at these other DOE sites.
- Provide fundamental research in environmental sciences, biology, molecular sciences, and computational modeling that will underpin the cleanup of contaminated sites.

Medical Applications and Measurement Science

- **DOE Technology Applied to Biomedicine** - The BER Medical Applications program initiated pilot projects in biomedical engineering for practical utilization of knowledge of physics, chemistry, biology, and engineering to develop new technologies for the diagnosis, prevention, and treatment of disease. DOE is also partnering with other agencies as a member of BECON, the Federal Bioengineering Consortium. Patient accrual in BNCT clinical trial has stopped and careful clinical follow-up of all treated patients continues.

- **High Tech Imaging Systems Used to Study Addiction** - A new Brookhaven National Laboratory study demonstrated that cocaine addicted rats, when treated with an epilepsy drug, gamma vinyl-gamma-aminobutyric acid (GVG), reduced their intake of cocaine and didn't exhibit the ability to acquire or express behaviors associated with its addiction. Also positron emission tomography (PET) radiotracer studies in primates clearly demonstrated that GVG prevents the dopamine surge that cocaine normally causes. These promising results in animals indicate that GVG may prove to be an effective pharmaceutical treatment for cocaine addiction, and it may be useful for the treatment of other addictions.
- **Toxic Drug Effects on Brain Localized** - Brain PET imaging studies show that methamphetamine is toxic to the brain and this is associated with long term memory and motor impairment. Studies are in progress to determine if recovery occurs on drug withdrawal.

The BER program continues its commitment to and dependence on research scientists at our nation's universities. University-based scientists are an integral part of research programs across the entire range of the BER portfolio. These scientists are funded through individual peer-reviewed grants and as members of peer-reviewed research teams involving both national laboratory and university scientists.

University-based scientists are the principal users of BER user facilities for structural biology, at the Environmental Molecular Sciences Laboratory, and the Natural and Accelerated Bioremediation Research (NABIR) Program's Field Research Center. University scientists also form the core of the Atmospheric Radiation Measurement (ARM) science team that networks with the broader academic community as well as with scientists at other agencies, such as the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration. In addition, university-based scientists are funded through their response to Requests for Applications across the entire BER program including genomics, structural biology, low dose radiation research, global change research, microbial cell project, bioremediation research, medical imaging, radiopharmaceutical development, and biomedical engineering. Furthermore, university scientists work in close partnership with scientists at national laboratories in many BER programs including genomics, the Climate Change Technology Initiative (CCTI), and biomedical engineering.

Scientific Facilities Utilization

The Biological and Environmental Research request includes $52,665,000 to maintain support of the Department's scientific user facilities. Facilities used for structural biology research, such as beam lines at the synchrotron light sources and research reactors are included. The request also includes operation of the William R. Wiley Environmental Molecular Sciences Laboratory where the research activities will underpin long-term environmental remediation. This funding will provide for the operation of the facilities, assuring access for scientists in universities, federal laboratories, and industry. It will also leverage both federally and privately sponsored research.

New Research Programs in the Life and Medical Sciences

The FY 2001 budget includes funds for a new research program, the Microbial Cell project. This project capitalizes on DOE's pioneering and leadership role in high throughput genomic DNA sequencing; its longstanding support of microbial biochemistry, metabolism and physiology; its support of national user facilities for determining protein structures; and the capabilities of its national laboratories in computational analysis and instrumentation research. The goal of the Microbial Cell project is to develop a comprehensive understanding of the complete workings of a microbial cell, from the DNA sequence, to the identification of all the genes, to the production of all the proteins whose assembly instructions are contained in the genes, to the complex interaction of the genes and proteins in a cell that give the microbe its life and its unique characteristics and behaviors.

The key scientific challenges are far greater than "simply" understanding how individual genes and proteins work. We need to understand how genes and proteins are regulated in a coordinated manner and how they are integrated into a functional, interactive cell. This project will challenge scientists to go beyond the leveraging of tools and technologies for high throughput DNA sequencing and will require high throughput approaches for determining the structure and function of proteins, computational biology and bioinformatics resources, the development and use of sophisticated imaging and analytical sensing technologies, and approaches for modeling and analyzing complex systems.

This information will address DOE needs in energy use and production, bioremediation, and carbon sequestration and will provide exciting, new, and previously unavailable information to the entire biological community.

The FY 2001 budget also includes an increase for a recently initiated research program in Biomedical Engineering. The Biomedical Engineering program will nurture collaborations between the DOE National Laboratories and leading medical schools and teaching hospitals. These collaborations will leverage the Laboratories' unique resources and expertise in the biological, physical, chemical, engineering, and computing sciences to provide innovative and high-risk solutions to medical application problems dealing with the diagnosis, prevention, and treatment of disease. The program is a natural extension of the nuclear medicine field that BER originated and has supported for over half a century.

Recently, the National Institutes of Health (NIH) has recognized the potential of BER to contribute to the advancement of bioengineering research and has accepted BER as a member of the Bioengineering Consortium (BECON). BECON also involved all the individual NIH institutes and the NSF with the goal of fostering new basic understandings, collaborations, and transdisciplinary training in bioengineering.

The BER Biomedical Engineering program will be coordinated with BECON activities and will utilize the BECON expertise to validate the medical relevance of cutting-edge technological advances in the National Laboratories involving, e.g., biological therapies, materials, processes, implants, devices, and information systems. Awards will be made following competitive solicitations that stress lab-academic partnerships.

Climate Change Technology Initiative

The FY 2001 budget contains two-carbon related programs; each is coordinated with several offices and agencies. The first is the Climate Change Technology Initiative (CCTI). The second is the U.S. Global Change Research Program (US/GCRP). US/GCRP research focuses on developing the fundamental understanding of the comprehensive climate system and the global and regional manifestations of climate change. CCTI focuses on the underpinning fundamental science that will enable mitigation and adaptation to climate change. The two complementary programs are described in "A U.S. Carbon Cycle Science Plan," a report proposed by the US/GCRP and the "Carbon Sequestration Research and Development Report" developed by the CCTI. All research in the CCTI is peer-reviewed fundamental scientific research that expands upon core research activities.

The component of CCTI conducted by the Office of Science is research on carbon management science. This includes the following three areas: sequestration science, science for efficient technologies and fundamental science to advance all low/no carbon energy sources. Research begun in the last two years that support advances in low/no carbon energy technologies are closely coordinated with DOE's technology programs and will provide the knowledge base for new advanced technologies to reduce carbon dioxide emissions. These activities will impact the Office of Energy Efficiency and Renewable Energy (EE) and the energy and transportation industry by providing options for increased efficiency and reduced energy consumption in manufacturing with improved sensors, controls, and processes. Other aspects of these research projects impact the Office of Fossil Energy (FE) by providing a foundation for effective and safe underground sequestration. The Office of Fossil Energy was an equal partner with the Office of Science in the development of the "Carbon Sequestration Research and Development Report."

The Office of Science has long-standing programs in fundamental research that already impact these three categories. In FY 2001, $19,504,000 is being requested by BES and $16,257,000 by BER specifically for the CCTI. Research begun under this initiative is complementary to work in several other research programs at DOE and at other agencies. Ongoing CCTI research includes two new centers for carbon sequestration, the sequencing of the DNA of several microbes critical to biological sequestration, and over 50 single investigator and interdisciplinary projects at universities and national laboratories. Research projects span a broad array of disciplines, including ecological, biological, and geological studies of sequestration science; chemical and biological studies of alternative energy sources; new concepts in light weight energy efficient materials; and more efficient combustion and conversion processes.

Funding of Contractor Security Clearances

In FY 1999, the Department divided the responsibility for obtaining and maintaining security clearances. The Office of Security Affairs, which was responsible for funding all Federal and contractor employee clearances, now pays only for clearances of Federal employees, both at headquarters and the field. Program organizations are now responsible for contractor clearances, using program funds. This change in policy enables program managers to make the decisions as to how many and what level clearances are necessary for effective program execution. In this way, it is hoped that any backlog of essential clearances that are impeding program success can be cleared up by those managers most directly involved. The Office of Science is budgeting $90,000 for estimated contractor security clearances in FY 2000 and FY 2001 within this decision unit.

Workforce Development

Workforce development is an integral and essential element of the BER mission to help ensure a science-trained workforce, including researchers, engineers, science educators, and technicians. BER research programs and projects at the national laboratories and in the private sector actively integrate undergraduate and graduate students and postdoctoral investigators into the work. This "hands-on" approach is essential for the development of the next generation of scientists, engineers, and science educators. Specific fellowship programs are also sponsored by BER to target emerging areas of need. A total of 1,530 graduate students and post-doctoral investigators were supported at universities and at national laboratories in FY 1999. BER will continue its support for graduate students and post doctoral investigators in FY 2000 and FY 2001. The actual number of graduate students and post doctoral investigators is estimated to remain at the FY 1999 level.

Graduate students and post-doctoral investigators use Office of Science user facilities such as the structural biology experimental stations at beam lines at the synchrotron light sources and the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL). Using these unique research tools enables the graduate students and post-doctoral investigators to participate in and conduct leading edge research. Approximately half of all of the facility users are graduate students and post-doctoral investigators. The graduate students and post doctoral investigators are supported by resources from a wide variety of sponsors, including BER, other Departmental research programs, other federal agencies, and U.S. and international private institutions. Graduate students and post-doctoral investigators at the synchrotron light sources are included in the Basic Energy Sciences (BES) user facility statistics and are not included here. A total of 500 graduate students and post-doctoral investigators were supported at the EMSL in FY 1999.

Funding Profile

(dollars in thousands)

	FY 1999 Current Appropriation	FY 2000 Original Appropriation	FY 2000 Adjustments	FY 2000 Current Appropriation	FY 2001 Request
Biological and Environmental Research					
Life Sciences	173,379	173,264	-2,687	170,577	188,906
Environmental Processes	114,530	130,568	-3,452	127,116	131,509
Environmental Remediation	64,775	65,757	-906	64,851	63,536
Medical Applications and Measurement Science	73,206	71,911	-1,569	70,342	58,809
Subtotal, Biological and Environmental Research	425,890	441,500	-8,614	432,886	442,760
Construction	0	0	0	0	2,500
Subtotal, Biological and Environmental Research	425,890	441,500	-8,614	432,886	445,260
Use of Prior Year Balances	-3,798[a]	0	0	0	0
General Reduction	0	-3,878	3,878	0	0
Contractor Travel	0	-2,133	2,133	0	0
Omnibus Rescission	0	-2,603	2,603	0	0
Total, Biological and Environmental Research	422,092[b]	432,886	0	432,886	445,260[c]

Public Law Authorization:
Public Law 95-91, "Department of Energy Organization Act"
Public Law 103-62, "Government Performance Results Act of 1993"

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total reduction is applied at the appropriation level.

[b] Excludes $10,187,000 which was transferred to the SBIR program and $611,000 which was transferred to the STTR program.

[c] Includes $1,200,000 for Waste Management activities at Pacific Northwest National Laboratory that was previously budgeted in FY 2000 by the Environmental Management program.

Funding By Site

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	22,362	19,280	17,971	-1,309	-6.8%
Sandia National Laboratories	3,537	1,490	3,091	+1,601	+107.4%
Albuquerque Operations Office	3,575	2,800	1,550	-1,250	-44.6%
Total, Albuquerque Operations Office	29,474	23,570	22,612	-958	-4.1%
Chicago Operations Office					
Ames Laboratory	900	660	525	-135	-20.5%
Argonne National Laboratory –East	10,198	9,040	20,780	+11,740	+129.9%
Brookhaven National Laboratory	23,413	19,163	16,758	-2,405	-12.6%
Chicago Operations Office	91,244	59,572	47,108	-12,464	-20.9%
Total, Chicago Operations Office	125,755	88,435	85,171	-3,264	-3.7%
Idaho Operations Office					
Idaho National Engineering & Environmental Lab	2,084	1,761	1,489	-272	-15.4%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	39,163	43,581	40,532	-3,049	-7.0%
Lawrence Livermore National Laboratory	41,127	40,110	38,875	-1,235	-3.1%
Stanford Linear Accelerator Center	2,771	2,450	3,500	+1,050	+42.9%
Oakland Operations Office	68,606	46,704	37,871	-8,833	-18.9%
Total, Oakland Operations Office	151,667	132,845	120,778	-12,067	-9.1%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science & Education	3,553	3,593	4,079	+486	+13.5%
Oak Ridge National Laboratory	28,062	25,988	29,144	+3,156	+12.1%
Oak Ridge Operations Office	366	314	132	-182	-58.0%
Thomas Jefferson National Accelerator Facility	260	0	0	0	0.0%
Total, Oak Ridge Operations Office	32,241	29,895	33,355	+3,460	+11.6%
Richland Operations Office					
Pacific Northwest National Laboratory	79,879	64,339	65,312	+973	+1.5%
Washington Headquarters	4,790	92,041	116,543	+24,502	+26.6%
Subtotal, Biological and Environmental Research	425,890	432,886	445,260	+12,374	+2.9%
Use of Prior Year Balances	-3,798[a]	0	0	0	0.0%
Total, Biological and Environmental Research	422,092[b]	432,886	445,260[c]	+12,374	+2.9%

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total reduction is applied at the appropriation level.

[b] Excludes $10,187,000 which was transferred to the SBIR program and $611,000 which was transferred to the STTR program.

[c] Includes $1,200,000 in FY 2001 for Waste Management activities at Pacific Northwest National Laboratory that was previously budgeted in FY 2000 by the Environmental Management program.

Site Description

Ames Laboratory

Ames Laboratory is a Multiprogram Laboratory located on 10 acres in Ames, Iowa. At Ames, BER supports research into new biological imaging techniques such as fluorescence spectroscopy to study environmental carcinogens.

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. At ANL, BER supports the operation of a high-throughput national user facility for protein crystallography at the Advanced Photon Source, and research in protein structure relating to the process of photosynthesis. In support of Global Change research, ANL coordinates the operation and development of the Southern Great Plains ARM site. The principal scientist for the Atmospheric Chemistry program is at ANL, providing broad scientific integration to the program. Research is conducted to understand the molecular control of genes and gene pathways in both microbes and mammalian cells and molecular factors that control cell responses to low doses of radiation. ANL, in conjunction with ORNL and PNNL and six universities, co-hosts a terrestrial carbon sequestration research center.

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. BER supports the operation of beam lines for protein crystallography at the National Synchrotron Light Source for use by the national biological research community, research in biological structural determination, research and operation of the protein structure database, and research into new instrumentation for detecting x-rays and neutrons. Research is also conducted on the molecular mechanisms of cell responses to low doses of radiation.

The Boron Neutron Capture Therapy (BNCT) program supports early clinical trials of this concept for treatment of brain cancers that do not respond to conventional treatment. The nuclear medicine program supports research into novel techniques for imaging brain function in normal and diseased states.

Global change activities at BNL include the operation of the ARM External Data resource that provides ARM investigators with data from non-ARM sources, including satellite and ground-based systems. BNL scientists form an important part of the science team in the Atmospheric Sciences program, providing special expertise in atmospheric field campaigns and aerosol research. BNL scientists play a leadership role in the development of, and experimentation at, the Free Air Carbon Dioxide Enhancement (FACE) at the Duke Forest.

Idaho National Engineering and Environmental Laboratory

Idaho National Engineering and Environmental Laboratory is a Multiprogram Laboratory located on 572,000 acres in Idaho Falls, Idaho. BER supports research into boron chemistry, radiation dosimetry, analytical chemistry of boron in tissues, and engineering of new systems for application of this treatment technique for brain and other tumors. Research into the analytical chemistry of complex environmental and biological systems using the technique of mass spectrometry is also supported.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory (LBNL) is a Multiprogram Laboratory located in Berkeley, California. The Laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. LBNL is one of the major national laboratory partners that comprise the Joint Genome Institute (JGI) whose principal goals are high throughput human DNA sequencing and studies on the biological functions associated with newly sequenced human DNA. A significant component of the JGI's sequencing goal is the development and integration of instrumentation, automation, biological resources, and data management and analysis tools into a state-of-the-art DNA sequencing assembly line that is highly efficient and cost effective. The laboratory also conducts research on the molecular mechanisms of cell responses to low doses of radiation and on the use of model organisms to understand and characterize the human genome.

LBNL operates beam lines for determination of protein structure at the Advanced Light Source for use by the national biological research community, research into new detectors for x-rays, and research into the structure of membrane and other proteins.

Research is conducted into the use of accelerators to produce neutrons for boron neutron capture therapy, an alternative treatment for highly malignant brain tumors. The nuclear medicine program supports research into novel radiopharmaceutical for medical research and studies of novel instrumentation for imaging of living systems for medical diagnosis.

LBNL supports the Natural and Accelerated Bioremediation Research (NABIR) program and the field geophysical - biophysical research capabilities for NABIR field sites. BER supports research into new technologies for characterization of complex environmental contamination. LBNL also develops scalable implementation technologies that will allow widely used climate models to run effectively and efficiently on massively parallel processing supercomputers.

LBNL co-hosts, with LLNL and six universities, an ocean carbon sequestration research center.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on a 821 acre site in Livermore, California. LLNL is one of the major national laboratory partners that comprise the Joint Genome Institute (JGI) whose principal goals are high throughput human DNA sequencing and studies on the biological functions associated with newly sequenced human DNA. A significant component of the JGI's sequencing goal, is the development and integration of instrumentation, automation, biological resources, and data management and analysis tools into a state-of-the-art DNA sequencing assembly line that is highly efficient and cost effective. LLNL also conducts research on the molecular mechanisms of cell responses to low doses of radiation, on the use of model organisms to understand and characterize the human genome, and on the development of new technologies for determining the structures of many more proteins than is currently possible.

Through the Program for Climate Model Diagnostics and Intercomparison, LLNL provides the international leadership to understand and improve climate models.

LLNL co-hosts, with LBNL and six universities, an ocean carbon sequestration research center.

Los Alamos National Laboratory

Los Alamos National Laboratory (LANL) is a Multiprogram Laboratory located on a 27,000 acre site in Los Alamos, New Mexico. LANL is one of the major national laboratory partners that comprise the Joint Genome Institute (JGI) whose principal goals are high throughput human DNA sequencing and studies on the biological functions associated with newly sequenced human DNA. A significant component of the JGI's sequencing goal is the development and integration of instrumentation, automation, biological resources, and data management and analysis tools into a state-of-the-art DNA sequencing assembly line that is highly efficient and cost effective. LANL also conducts research on the molecular mechanisms of cell responses to low doses of radiation and to understand the molecular control of genes and gene pathways in microbes. Activities in structural biology include the operation of an experimental station for protein crystallography at the Los Alamos Neutron Science Center for use by the national biological research community and research into new techniques for determination of the structure of proteins.

LANL coordinates the operation and development of the Tropical Western Pacific ARM site. LANL also has a crucial role in the development, optimization, and validation of coupled atmospheric and oceanic general circulation models on massively parallel computers.

LANL also conducts research into advanced medical imaging technologies for studying brain function and research into new techniques for rapid characterization and sorting of mixtures of cells and cell fragments.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on a 150 acre site in Oak Ridge, Tennessee. ORISE coordinates several research fellowship programs for BER. ORISE also coordinates activities associated with the peer review of all BER-funded science.

ORISE conducts research into modeling radiation dosages for novel clinical diagnostic and therapeutic procedures.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. ORNL has a leadership role in research focused on the ecological aspects of global environmental change. The Throughput Displacement Experiment at the Walker Branch Watershed is a unique resource for long term ecological experiments. ORNL is the home of the newest FACE experiment supported by BER. ORNL also houses the ARM archive, providing data to ARM scientists and to the general scientific community. ORNL scientists provide improvement in formulations and numerical methods necessary to improve climate models. ORNL scientists make important contributions to the NABIR program, providing special leadership in microbiology applied in the field.

ORNL conducts research on widely used data analysis tools and information resources that can be automated to provide information on the biological function of newly discovered genes identified in high throughput DNA sequencing projects. The laboratory also conducts research on the use of model organisms to understand and characterize the human genome and on the molecular mechanisms of cell responses to low doses of radiation.

ORNL conducts research into the application of radioactively labeled monoclonal antibodies in medical diagnosis and therapy, particularly of cancer, as well as research into new instrumentation for the analytical chemistry of complex environmental contamination using new types of biosensors.

ORNL recently has upgraded the High Flux Isotope Reactor (HFIR) to include a cold neutron source that will have high impact on the field of structural biology. BER is developing a station for Small Angle Neutron Scattering at HFIR to serve this research community.

ORNL, in conjunction with ANL and PNNL and six universities, co-hosts a terrestrial carbon sequestration research center.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. PNNL is home to the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL). PNNL and EMSL scientists play important roles in both supporting the NABIR program and in performing NABIR research.

PNNL operates the unique ultrahigh field mass spectrometry and nuclear magnetic resonance spectrometry instruments at the Environmental Molecular Sciences Laboratory for use by the national biological research community.

PNNL provides the lead scientist for the Environmental Meteorology Program, the G-1 research aircraft, and expertise in field campaigns. PNNL provides the planning and interface for the Climate Change Prediction Program with other climate modeling programs. The ARM program office is located at PNNL, as is the ARM chief scientist and the project manager for the ARM data system; this provides invaluable logistical, technical, and scientific expertise for the program. PNNL is developing the Second Generation Model for predicting the benefits and costs of policy actions with respect to global climate change.

PNNL conducts research into new instrumentation for microscopic imaging of biological systems and for characterization of complex radioactive contaminants by highly automated instruments.

PNNL also conducts research on the molecular mechanisms of cell responses to low doses of radiation.

PNNL, in conjunction with ANL and ORNL and six universities, co-hosts a terrestrial carbon sequestration research center.

Sandia National Laboratories

Sandia National Laboratories (SNL) is a Multiprogram Laboratory, with a total of 3,700 acres, located in Albuquerque, New Mexico, with sites in Livermore, California, and Tonapah, Nevada. SNL coordinates the operation and development of the North Slope of Alaska ARM site. The chief scientist for the ARM-UAV program is at SNL, and SNL takes the lead role in coordinating and executing ARM-UAV missions.

To support environmental cleanup, SNL conducts research into novel sensors for analytical chemistry of contaminated environments.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center (SLAC) is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California, and is the home of the Stanford Synchroton Radiation Laboratory (SSRL). The Stanford Synchrotron Radiation Laboratory was built in 1974 to utilize the intense x-ray beams from the SPEAR storage ring that was built for particle physics by the SLAC laboratory. Over the years, the SSRL grew to be one of the main innovators in the production and use of synchrotron radiation with the development of wigglers and undulators that form the basis of all third generation synchrotron sources. The facility is now comprised of 25 experimental stations and is used each year by over 700 researchers from industry, government laboratories and universities. Through the Stanford Linear Accelerator Center, BER (in coordination with the National Institutes of Health) is funding the operation of Stanford Synchrotron Radiation Laboratory beam lines for structural biology. This program involves synchrotron radiation-based research and technology developments in structural molecular biology that focus on protein crystallography, x-ray small angle scattering diffraction, and x-ray absorption spectroscopy for determining the structures of complex proteins of many biological consequences.

All Other Sites

The BER program funds research at over 340 institutions, including colleges/universities, private industry, and other federal and private research institutions located in 47 states. Also included are funds for research awaiting distribution pending completion of peer review results.

BER supports a broad range of peer-reviewed research at America's universities, including institutions that traditionally serve minority communities. Research opportunities are announced through public solicitations in the Federal Register for research applications from universities and the private sector.

Life Sciences research is conducted at a large number of universities in all aspects of the program. Research is conducted in support of high throughput human DNA sequencing at the JGI, on the sequencing of entire microbial genomes with value to the DOE mission, to understand the molecular control of genes and gene pathways in microbes, on the use of model organisms to understand and characterize the human genome, and on the molecular mechanisms of cell responses to low doses of radiation.

In structural biology, universities provide new imaging detectors for x-rays, research in computational structural biology directed at the understanding of protein folding, and research into new techniques such as x-ray microscopy.

Peer reviewed projects are supported in each element of the Environmental Processes subprogram, with very active science teams, in particular, in the Atmospheric Chemistry Program and the ARM programs. Academic investigators are essential to the Integrated Assessment portfolio.

NABIR research grants are awarded following the peer review of applications received in response to solicitations published in the federal register. Academic and private sector investigators are performing research in areas that include mechanistic studies of bioremediation of actinide and transition metal contamination, the structure of microbial communities in the presence of uranium and other such contaminants, gene function in microorganisms with degradative properties, geochemical and enzymatic processes in microbial reduction of metals, and the use of tracers to monitor and predict metabolic degradative activity.

In nuclear medicine, universities conduct research into new types of radiopharmaceutical, particularly those based on application of concepts from genomics and structural biology. Emphasis is placed on radiopharmaceuticals that will be of use in advanced imaging techniques such as positron emission tomography. Research is supported into new instrumentation for medical imaging. The Boron Neutron Capture Therapy program supports studies of novel boron compounds for use in treating brain cancer, early clinical trials of the technique, and new instrumentation based on accelerators that could be used in hospitals and clinics. The Measurement Science program supports research into novel types of biosensors for application in analytical chemistry of contaminated environments.

Life Sciences

Mission Supporting Goals and Objectives

Research is focused on utilizing unique DOE resources and facilities to develop fundamental biological information and advanced technologies for understanding and mitigating the potential health effects of energy development, energy use, and waste cleanup. Research is conducted in five areas: structural biology, cellular biology, molecular biology, human genome, and health effects. The research:

- Develops and supports user facility infrastructure for the Nation's structural biologists; combines computer science, structural biology, and genome research for analyses and predictions of gene products at the individual protein and genomic levels; and develops new technologies and methodologies to understand the dynamic processes of protein-protein interactions at the cellular dimension that are unique to living organisms.
- Determines if low dose and low dose-rate radiation present a health risk to people that is the same as or greater than the health risk resulting from the oxidative by-products of normal physiological processes, providing a better scientific basis for achieving acceptable levels of human health protection.
- Determines the genomic DNA sequences of microbes with potential uses in energy, waste cleanup, and carbon management and uses that information to determine how microbes can be modified and/or exploited for DOE mission needs.
- Contributes to the International Human Genome Project by developing and applying new technologies and resources to map and determine the sequence of the subunits of DNA found in a typical human cell, to analyze and interpret DNA sequence data, and to study the ethical, legal, and social implications (ELSI) of information and data resulting from the genome project. Research emphasis is on high throughput, production sequencing of human DNA, rapid entry of data into public databases, and identifying the functions for a portion of the 100,000 genes that make up the human genome.
- Integrates and exploits information and technologies from genome, structural biology, and molecular biology research with human health research to understand the network of genes and proteins—that is the complex relationships between genes, the proteins they encode, and the biological functions of these proteins in the context of the whole organism.

Climate Change Technology Initiative

The Life Sciences subprogram's support of microbial genome research also underpins the Climate Change Technology Initiative. Knowing the genomic sequence of microbes that produce methane and hydrogen, will enable the identification of the key genetic and protein components of the organisms that regulate these gases. Understanding more fully how the enzymes and organisms operate, we will be able to evaluate their potential use to produce methane or hydrogen from either fossil fuels or other carbonaceous sources, including biomass or even some waste products. Recently discovered extremophile organisms could be used to engineer biological entities that could ingest a feedstock like methane, sequester the carbon dioxide, and produce hydrogen.

Microbial Cell Project

The goal of the Microbial Cell Project is to develop a comprehensive understanding of the complete workings of a microbial cell, from the DNA sequence, to the identification of all the genes, to the production of all the proteins whose assembly instructions are contained in the genes, to the complex interaction of the genes and proteins in a cell that give the microbe its life and its unique characteristics and behaviors. This information can be used to address DOE needs in energy use and production, bioremediation, and carbon sequestration and will provide exciting, new, and previously unavailable information to the entire biological community.

Performance Measures

- Microbial Genomics/Climate Change Technology Initiative: Complete the genetic sequencing of at least two additional microbes that produce methane or hydrogen from carbonaceous sources or that could be used to sequester carbon dioxide.
- High Throughput DNA Sequencing: By the end of FY 2001, the DOE Joint Genome Institute (JGI) will complete the sequencing and submission to public databases of 100 million finished and 250 million high quality draft base pairs of DNA, including both human and mouse.
- Develop program plan and make initial awards in Microbial Cell Project.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Structural Biology	26,900	27,474	35,645	+8,171	+29.7%
Molecular and Cellular Biology	35,572	31,376	44,029	+12,653	+40.3%
Human Genome	90,679	88,886	90,270	+1,384	+1.6%
Health Effects	20,228	18,328	14,476	-3,852	-21.0%
SBIR/STTR	0[a]	4,513	4,486	-27	-0.6%
Total, Life Sciences	173,379	170,577	188,906	+18,329	+10.7%

[a] Excludes $4,060,000 which has been transferred to the SBIR program and $243,000 which has been transferred to the STTR program.

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Structural Biology			
■ Infrastructure support and development for the Nation's structural biologists. Continue to coordinate with the National Institutes of Health and the National Science Foundation on the development and operation of experimental stations at DOE national user facilities such as the synchrotrons and neutron beam sources. Operate the neutron protein crystallography station at the Los Alamos Neutron Science Center (LANSCE). Initiate development of a new station for small angle neutron scattering at the High Flux Isotope Reactor at ORNL and support improvements in beamlines at SSRL. Support a protein database for three-dimensional protein structures. University-based scientists are the principal users of these user facilities. GPP funds ($3,000,000) will be used to complete a Laboratory Module at the Advanced Photon Source at Argonne National Laboratory. Initiated in FY 2000 with $3,000,000 from the National Institutes of Health's Institute of General Medical Sciences (NIGMS), the module is part of an NIGMS/DOE partnership to advance the field of structural biology. The estimated total federal cost of this laboratory module is $6,000,000. The Laboratory Module will provide space for four additional beamlines needed by the structural biology user community. In FY 2001, $4,500,000 is included for a major item of equipment, the DNA Repair Protein Complex Beamline project (Total Estimated Cost $4,500,000) at the Advanced Light Source at Lawrence Berkeley National Laboratory. This beamline will have novel features that include the ability to conduct both high resolution (2 Angstrom) and low resolution (2000 Angstrom) studies on important biomolecules using the same beamline. It will meet a rapidly growing need in the structural biology user community to provide unique information on functionally important conformation changes in and the regulation of assembly of multiprotein complexes..	15,471	16,000	23,500
■ Basic research in structural biology cuts across basic biology, molecular biology (including genomics), computational biology, and instrumentation development. Robust computational processes will be developed to predict the three-dimensional architecture and dynamic behavior of individual proteins and			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
protein complexes involved in the recognition and repair of DNA damage or the bioremediation of metals and radionuclides. New technologies and methodologies will be developed to understand the dynamic processes of protein-protein interactions and gene networks that are unique to living organisms.	11,429	11,474	12,145
Total, Structural Biology..	26,900	27,474	35,645

Molecular and Cellular Biology

- The field of microbial genomics continues to be one of the most exciting, high profile, and rapidly growing fields in biology today, expanding from the DOE-initiated program through other federal agencies and private industry. The BER Microbial Genome Program has supported the complete genomic sequencing of 15 of the approximately 50 bacteria whose DNA has been sequenced. The sequencing of more than 40 additional microbes is in progress in the scientific community. The broad impacts of this research emphasize a central principle of the BER genome programs – complete genomic sequences yield answers to fundamental questions in biology. Microbes are being sequenced and characterized in several parts of the BER program with potential impacts across several DOE missions including: the Climate Change Technology research (methane or hydrogen producing microbes or microbes involved in carbon dioxide sequestration), microbes for cleaning up the environment, alternative fuel sources (methane production or energy from biomass), and microbes that produce industrially useful enzymes. As the number of complete and in-progress microbial genomes grows, the microbial genome program is shifting its emphasis from a predominant focus on genomic sequencing to a broader emphasis on the use and discovery of new knowledge from microbes whose genomic DNA sequences have been determined. The program is closely coordinated with CCTI and the new Microbial Cell program, prividing them basic sequence information. The program will begin to place an increased emphasis on (1) identifying a broader array of potentially useful microbes, especially from DOE relevant sites, such as waste sites; and (2) new strategies for determining the DNA sequence of microbes for which the complete sequence of a very closely related microbe is already known, to avoid the need for costly and time consuming sequencing of many important microbes from scratch. A new emphasis will be placed on the development of high throughput technologies to determine the function of the thousands of new genes that have been and continue to be

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
discovered as part of the determination of the complete DNA sequence of microbes. Between one quarter and one third of all genes identified through DNA sequencing are new genes whose functions are not known. To fully leverage the biological capabilities of a microbe for clean up, fuel production, etc., the function of most or all of that microbe's genes needs to be known. Together with the microbial genes whose functions we already know, these new genes represent a treasure chest of biological potential that can be used or modified to address DOE mission needs.	9,633	8,594	14,117
■ The Climate Change Technology Initiative (CCTI) continues to determine the DNA sequence of microbes that produce methane or hydrogen from carbonaceous sources or that could be used to sequester carbon dioxide. The genomic sequence of five microbes involved in carbon management will have been determined by FY 2001. Research to characterize key reaction pathways or regulatory networks in these microbes, that focus on the development of practical uses for microbes within the CCTI, will be emphasized. Together, with the new, high-throughput technologies that will be developed to determine the function of new genes discovered from the sequencing of a microbe's DNA, the information on the DNA sequence, key reaction pathways, and regulatory networks will be used to address the fuel production or carbon sequestration goals of the CCTI.	2,434	5,841	7,495
■ The Microbial Cell Project – Understand the complete workings of a microbial cell and use this information to address DOE needs in energy use and production, bioremediation, and carbon sequestration. The Microbial Cell Project represents a fundamental shift in our approach to biology. Instead of looking from the outside of an organism in, starting with its behavior and features and finding the responsible genes, we will start with the complete DNA sequence or parts list and work from the inside out to identify and understand the structures, functions, and interactions of an organism's entire complement of genes and gene products. Develop a comprehensive understanding of the complete workings of a microbial cell by: deciphering the individual gene sequence; understanding how the sequence is controlled; understanding the production of the genes' protein products; and understanding the complex interaction of all the genes and proteins in a cell. Identify and characterize a minimum set of genes, proteins, and metabolic capabilities that are both necessary and sufficient for the microbe to survive. Characterize			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
the cell machinery and regulatory pathways responsible for making, transporting, and using all of the products needed for a microbe to survive. Use microbes to address DOE mission needs, e.g., degradation or sequestration of hazardous wastes; efficient degradation of cellulose for producing food stocks and fuels. Key scientific challenges include understanding how individual genes and proteins work; how they are regulated in a coordinated manner; and how they are integrated into functional, interactive cells. Key technical challenges include the use and continued development of tools for high throughput DNA sequencing, protein structure determination, computational biology and bioinformatics, sophisticated imaging and analytical sensing technologies, and complex systems analysis. Initially the Microbial Cell Project will focus on genomic DNA sequencing, comparative genomic DNA sequence analysis, protein structure determination, computational analysis of protein structure, analysis of metabolic pathways, computational models of regulatory pathways, analysis of protein-protein interactions, and imaging protein distributions and interactions..............................	0	0	9,735
■ Congressional direction for FY 1999 for the Institute for Molecular Biology and Medicine, University of Scranton, Scranton, Pennsylvania..	10,189	0	0
■ Molecular biology research, as a general research area, comes to an end and is replaced by microbial genome research. Funding continues for the Human Frontiers Science Program, an international program of collaborative research to understand brain function and biological function at the molecular level supported by the U.S. government through the DOE, the National Institutes of Health, the National Science Foundation, and the National Aeronautics and Space Administration.	1,000	1,000	1,000
■ The low dose radiation research program supports basic research to determine if low dose and low dose-rate radiation present a health risk to people that is the same as or greater than the health risk resulting from the oxidative by-products of normal physiological processes. This information is a key determinant in decisions that are made to protect people from adverse health risks from exposure to radiation. Research is funded as part of a collaborative and highly coordinated program with the Office of Environmental Management. Information resulting from the program is made broadly available to scientists, the public, regulators, and Congress through interactive scientific meetings, web sites, and educational materials. Research conducted in this			

	FY 1999	FY 2000	FY 2001
Program will help determine health risks from exposures to low levels of radiation, information that is critical to adequately and appropriately protect people and to make the most effective use of our national resources. This information will provide a better scientific basis for remediating contaminated DOE sites and achieving acceptable levels of human health protection, both for cleanup workers and the public, in a more cost-effective manner that could save billions of dollars. University scientists, competing for funds in response to requests for applications, conduct a substantial fraction of the research in this program. In FY 2000, the research was funded within Cellular Biology and Health Effects. In FY 2001, the research has been consolidated in Cellular Biology.	8,000	14,203	11,682
■ Congressional direction in FY 2000 for a Study of Avian Populations at the Nevada Test Site.	0	94	0
■ Congressional direction in FY 2000 for a review of the Hiroshima neutron dosimetry.	0	1,644	0
■ Cellular biology research, as a general research area, comes to an end and is replaced by the low dose radiation research program.	4,316	0	0
Total, Molecular and Cellular Biology	35,572	31,376	44,029

(dollars in thousands)

Human Genome

- The Joint Genome Institute (JGI) and its Production Sequencing Facility (PSF) are primarily focused on high throughput sequencing of DNA. The JGI, a virtual institute initially formed from the combined strengths and expertise of DOE Human Genome Centers at the Los Alamos, Lawrence Livermore, and Lawrence Berkeley National Laboratories, is expanded to include other National Laboratories that diversify and strengthen its overall capabilities. FY 2001 is the fourth year of a major five year scale-up of DNA sequencing capacity at the PSF. In FY 2000 the PSF will have completed draft sequences of human chromosomes 5, 16, and 19 as part of its commitment to the International Human Genome Project. In FY 2001 the PSF will make substantial progress towards finishing the high quality sequence of those three chromosomes to international “Bermuda” quality standards. University scientists, working with the JGI, play a key role in completing DOE’s share of determining the human DNA sequence. The PSF will initiate draft sequencing

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
of regions of the mouse genome that are comparable to these three human chromosomes. This comparative information is critical to understanding gene function, networks, and regulation.	50,000	59,500	59,500
■ Research continues to develop the tools and resources needed by the scientific, medical, and private sector communities to fully exploit the information contained in the first complete human DNA sequence. Unimaginable amounts of DNA sequencing, at dramatically increased speed and reduced cost, will be required in the future for medical and commercial purposes. Research is conducted to further improve the reagents used in DNA sequencing and analysis; to decrease the costs of sequencing; to increase the speed of DNA sequencing; and to improve strategies for sequencing the "difficult regions" at the ends and middle of chromosomes. Use of sequence information to understand human biology and disease will require new strategies and tools capable of high throughput, genome-wide experimental and analytic approaches. Research is conducted to develop high throughput approaches for analyzing gene regulation and function. A table follows displaying both DOE and NIH genome funding.	38,119	26,719	28,218
■ The Ethical Legal and Societal Issues (ELSI) program continues to broaden its emphasis on research related to the uses, impacts, and implications of genetic information in the workplace and the use of the workplace as a research environment.	2,560	2,667	2,552
Total, Human Genome	90,679	88,886	90,270

U.S. Human Genome Project Funding

	(dollars in millions)			
	Prior Years	FY 1999	FY 2000	FY 2001
DOE Total Funding...	542.5	90.7	88.9	90.3
NIH Funding..	1,452.4	264.9	336.0	TBD
Total U.S. Funding...	1,994.9	355.6	424.9	TBD

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Health Effects			
■ Low dose radiation research (consolidated in Cellular Biology in FY 2001) was also funded in Health Effects in FY 2000. The low dose radiation research program, provides information that is a key determinant in decisions made to protect people from adverse health risks from exposure to radiation. This information will provide a better scientific basis for remediating contaminated DOE sites and achieving acceptable levels of human health protection, both for cleanup workers and the public, in a more cost-effective manner that could save billions of dollars.	0	2,321	0
■ Model organism research capitalizes on our understanding and the manipulability of the genomes of organisms, including yeast, nematode, fruitfly, Zebra fish, and mouse, to speed understanding of human genome organization, regulation, and function. This research is a key link between human genomic sequencing, that provides a complete parts list for the human genome, and the development of information (a high-tech owner's manual) that is useful in understanding normal human development and disease processes	9,337	11,501	11,027
■ Technology development research results in new approaches, tools, or technologies for determining the structures of many more proteins than is currently possible. This research is closely coordinated with structural biology and genomic (both human and microbial) research.	3,000	4,506	3,449
■ Biological research, as a general research area, comes to an end and is replaced by low dose radiation, model organisms, and technology development research.	7,891	0	0
Total, Health Effects	20,228	18,328	14,476
SBIR/STTR			
■ In FY 1999, $4,060,000 and $244,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts are the estimated requirements for the continuation of these programs.	0	4,513	4,486
Total, Life Sciences	173,379	170,577	188,906

Explanation of Funding Changes From FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Structural Biology	
■ Increased GPP funding for completion of a Laboratory Module to house four structural biology beamlines at the Advanced Photon Source at Argonne National Laboratory.	+3,000
■ Increased funding for a Major Item of Equipment, a DNA repair protein complex beamline, at the Advanced Light Source at Lawrence Berkeley National Laboratory.	+4,500
■ Increased basic research to understand the structures of protein complexes involved in the recognition and repair of DNA damage and in the bioprocessing of metals and radionuclides.	+671
Total, Structural Biology	+8,171
Molecular and Cellular Biology	
■ Increased technology development research that develops high throughput approaches for understanding the functions of newly discovered microbial genes.	+5,523
■ Increased CCTI research to identify and characterize genes and proteins involved in biofuel production or carbon sequestration.	+1,654
■ New research program, Microbial Cell Project, to understand the complete workings of a microbial cell from DNA sequence to the function and interactions of proteins	+9,735
■ Decrease research to understand the health impacts of low doses of radiation.	-2,521
■ Congressional direction in FY 2000 for a Study of Avian Populations at the Nevada Test Site.	-94
■ Neutron dosimetry research requested by Congress in FY 2000 is completed	-1,644
Total, Molecular and Cellular Biology	+12,653
Human Genome	
■ Increased basic research in long-term DNA sequencing technology because completion of the DNA sequence increases the need for faster, cheaper DNA sequencing technology to understand individual sequence variation and the sequence of important model organisms	+1,499

	FY 2001 vs. FY 2000 ($000)
■ Continue Ethical Legal and Societal Issues (ELSI) program at approximately same level as FY 2000	-115
Total, Human Genome	+1,384
Health Effects	
■ Decrease because research to understand the health impacts of low doses of radiation is consolidated in Cellular Biology above.	-2,321
■ Decrease due to transition of several projects in model organisms research, that develop new strategies for understanding the function of newly required human genes, to human genome research.	-474
■ Decrease technology development research for developing high throughput approaches that determine protein structure, to allow for growth in higher priority areas as a first step in the phase-out of this research program as NIH begins to make large investments in this area	-1,057
Total, Health Effects	-3,852
SBIR/STTR	
■ Decrease in SBIR/STTR.	-27
Total Funding Change, Life Sciences	+18,329

Environmental Processes

Mission Supporting Goals and Objectives

There are four contributing areas to the overall research program on environmental processes: Climate and Hydrology; Atmospheric Chemistry and Carbon Cycle; Ecological Processes; and Human Interactions. Research is focused on understanding the basic chemical, physical, and biological processes of the Earth's atmosphere, land, and oceans and how these processes may be affected by energy production and use, primarily the emission of carbon dioxide from fossil fuel combustion. A major part of the research is designed to provide the data that will enable an objective assessment of the potential for, and consequences of, global warming. The program is comprehensive with an emphasis on understanding the radiation balance from the surface of the Earth to the top of the atmosphere (including the role of clouds) and on enhancing the quantitative models necessary to predict possible climate change at the global and regional scales. The components of the Atmospheric Radiation Measurement (ARM) program continue to work in an integrated fashion to produce the experimental and modeling results that will be necessary to resolve the greatest uncertainty in climate prediction - the role of clouds and solar radiation. Climate modeling using massively-parallel supercomputers will simulate climate change, predict climate, and evaluate model uncertainties due to changes in atmospheric concentrations of greenhouses gases on decade to century time scales. The Atmospheric Science program acquires data to understand the atmospheric processes that control the transport, transformation, and fate of energy-related chemicals and particulate matter. Emphasis is placed on processes relating to new air quality standards for tropospheric ozone and particulate matter and relationships between air quality and climate change. The Carbon Cycle program is designed to study the natural carbon cycle, including quantifying the role of the terrestrial biosphere as a sink or source of carbon dioxide. The program on Ecosystem Research is designed to provide information on the effects of atmospheric and climate changes on terrestrial organisms and ecosystems, including the potential direct effects of increasing atmospheric carbon dioxide levels. The Environmental Processes subprogram includes funding for DOE's contribution to the U.S. Global Change Research Program that was codified by Congress in the Global Change Research Act of 1990 and for part of the Office of Science activities under the Climate Change Technology Initiative.

Climate Change Technology Initiative

The Atmospheric Chemistry and Carbon Cycle category supports basic research that promotes an understanding of the role that the terrestrial biosphere, atmospheric chemistry and transport, and human activities play in determining the composition and quality of the atmosphere. Complementing the activities in support of the U.S. Global Change Research Program, science for the Climate Change Technology Initiative (CCTI) seeks the understanding necessary to exploit the biosphere’s natural processes to enhance the sequestration of atmospheric carbon dioxide. It also seeks the understanding necessary to assess the environmental implications of purposeful enhancement and/or disposal of carbon in the terrestrial biosphere and the ocean. The CCTI includes research to identify and understand the environmental and biological factors or processes that limit the sequestration of carbon in these systems, and to develop approaches for overcoming such limitations to enhance sequestration. The research includes studies on ocean carbon sequestration, especially the role of marine microorganisms and by terrestrial ecosystems.

Performance Measures

- Five Intensive Operations Periods (IOPs) will be conducted on schedule at the Atmospheric Radiation Measurement (ARM) Southern Great Plains site. Data will be obtained from the second station on the North Slop of Alaska as planned. The third station in the Tropical Western Pacific, on Christmas Island, will become operational on schedule and within budget in accordance with the program plan.
- Compare initial results from the six Free-Air Carbon Dioxide Enrichment (FACE) experiments, summarizing the direct effects of elevated atmospheric carbon dioxide levels on the growth, productivity, species interactions, water use efficiency, and carbon sequestration of terrestrial plants.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Climate and Hydrology	65,839	67,213	72,309	+5,096	+7.6%
Atmospheric Chemistry and Carbon Cycle	26,952	34,979	35,644	+665	+1.9%
Ecological Processes	13,691	11,924	12,010	+86	+0.7%
Human Interaction..............................	8,048	9,614	8,170	-1,444	-15.0%
SBIR/STTR	0[a]	3,386	3,376	-10	-0.3%
Total, Environmental Processes	114,530	127,116	131,509	+4,393	+3.5%

Detailed Program Justification

(dollars in thousands)

FY 1999	FY 2000	FY 2001

Climate and Hydrology

- **Climate Modeling:** Improved simulations provide the scientific basis for predicting climate and its implications for future decades. Develop next generation coupled atmosphere-ocean general circulation models with improved resolution to approximately 200 km grid size. Additionally, develop improved climate observational databases for testing and verifying the models. Support will continue for needed computational resources

[a] Excludes $2,800,000 which has been transferred to the SBIR program and $169,000 which has been transferred to the STTR program.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
on the supercomputers at the LANL Advanced Computing Laboratory. Increased budget will support the following: Analyze, develop, and implement methods to downscale global climate model simulations to smaller scales for regional studies of environmental changes using a hierarchy of applied and engineering models. Develop and employ technologies that can quickly and efficiently work with large and distributed and archived sets of both observational and modeling data to produce data sets suitable for study of regional changes in climate and their impacts. Two multi-institutional teams involving national laboratories and universities will be established to access the primary data archive and computational facilities. With its partners in the multi-agency U.S. Global Change Research Program, DOE will continue to fund two multi-institutional model development consortia for research on fully coupledcomprehensive models for simulating multi-decade and multi-century changes of the global environment at regional resolution. Included in these activities is implementation of collaboratory technology to facilitate interaction and speed progress.	22,092	23,845	27,962
■ **Atmospheric Radiation Measurement (ARM):** The Atmospheric Radiation Measurement (ARM) infrastructure program develops, supports, and maintains the three ARM sites and associated instrumentation. Continue operation of over two hundred instruments at the Southern Great Plains site. Begin limited operations of the third Tropical Western Pacific station. Provide data to scientific community through the ARM Archive.	28,454	27,371	27,371
■ **Atmospheric Radiation Measurement (ARM):** ARM research will support about 50 principal investigators working on cloud physics and on solar and infrared radiation interactions with water vapor and aerosols. University scientists form the core of the ARM science team that networks with the broader academic community as well as with scientists at other agencies, such as NASA and NOAA. More than 75 peer reviewed papers and twice that number of conference papers will be published. Realignment of the ARM Science Team to bring more emphasis on use of ARM observations to develop parameterizations and approaches useful to GCMs will be entering its second cycle. ARM Fellows established at the National Center for Atmospheric Research and at the European Center for Medium-range Weather Forecasting will increase ARM's involvement with centers that focus on the			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
development and testing of climate models. Enhance interactions with prominent climate modeling centers, including those supported by the NSF and by NOAA. Formal coordination of ARM Science Team activities will be implemented through the established working groups. Additional field studies will focus on connection of ARM data with carbon cycle research.	12,425	13,145	14,093
■ **Atmospheric Radiation Measurement (ARM)/Unmanned Aerial Vehicles (UAV):** One mission will be executed in concert with the ARM International Water Vapor Project to aid in the testing and evaluation of ground measurement of water vapor profiles. Data analysis from the absorption experiment conducted in FY 2000 will be assessed to determine if further missions are required..	2,868	2,852	2,883
Total, Climate and Hydrology...	65,839	67,213	72,309

Atmospheric Chemistry and Carbon Cycle

■ Atmospheric Science programs acquire data to understand the atmospheric processes that control the transport, transformation, and fate of energy-related chemicals and particulate matter. Emphasis is placed on processes relating to new air quality standards for tropospheric ozone and particulate matter and relationships between air quality and climate change. Field and laboratory studies are conducted in both atmospheric chemistry and environmental meteorology and acquired data are used to develop and validate predictive models for energy-related processes. Included are studies of chemical and physical processes affecting air pollutants such as sulfur and nitrogen oxides, tropospheric ozone, etc., gas-to-particle conversion processes, and the deposition and resuspension of associated aerosols, and studies to improve understanding of the meteorological processes that control the dispersion of energy-related chemicals and particulates in or released to the atmosphere. Much of this effort involves multi-agency collaboration. University scientists play key roles in this research program.	14,307	12,641	12,318

■ Continue supporting the existing AmeriFlux Program, and implement flux and carbon process measurements at 10 additional locations. The flux measurements will be linked to North American atmospheric measurement campaigns examining atmosphere-biosphere CO_2 exchange relationships.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
An expected outcome of these coordinated studies is an improved estimate of the strength of the terrestrial carbon sinks. AmeriFlux network operations will continue to measure net exchange of CO_2 and other greenhouse gases. Net ecosystem carbon uptake is estimated from the flux measurements, and the systems also provide unique data on water vapor exchange and energy balance of ecosystems. Refinement and testing of carbon cycle models will continue, and both mechanistically based and carbon accounting models will be used to estimate potential carbon sequestration for different linkages with biogeochemicalcycles and climate variation. Using tools of microbiology, linkages between carbon and nitrogen cycles in marine microbes will be investigated in partnership with other institutions conducting traditional research in oceanography.	8,752	14,118	14,564
■ Congresssional direction in FY 1999 and 2000 for the National Energy Laboratory in Hawaii.	971	1,405	0
■ Under the Climate Change Technology Initiative, enhance support of two carbon sequestration research centers. One center which is led by ORNL, PNNL, and ANL, and involving six collaboratory universities, focuses on terrestrial sequestration ($3,000,000). The other center, which is led by LBNL and LLNL, and involves collaboration with six universities and research institutions, focuses on ocean sequestration ($2,000,000). The centers develop the information needed to develop ways of enhancing the natural sequestration of carbon in terrestrial soils and vegetation and in the deep ocean. Support research on cellular and biogeochemical processes that control the rate and magnitude of carbon sequestration in terrestrial and oceanic systems, including the identification of pathways and processes that could be modified to enhance the net flow of carbon from the atmosphere to both terrestrial plants and, ultimately, to soils, and to the ocean surface and, ultimately, to the deep ocean. Also support research needed to assess the environmental implications of enhancing carbon sequestration and storage in the ocean and in terrestrial systems.	2,922	6,815	8,762
Total, Atmospheric Chemistry and Carbon Cycle	26,952	34,979	35,644

Ecological Processes

■ Continue the five Free-Air Carbon Dioxide Enrichment (FACE) experiments to improve understanding of the direct effects of elevated carbon dioxide and other atmospheric changes on the structure of functioning of various types of terrestrial

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
ecosystems, including coniferous and deciduous forests, grasslands, and desert. Continue the long-term experimental investigation on the Walker Branch Watershed in Tennessee to improve understanding of the direct and indirect effects of alterations in annual average precipitation on the functioning and structure of a southeastern deciduous forest ecosystem. University scientists play key roles in this program.	13,691	11,924	12,010
Human Interactions			
■ The Integrated Assessment program, with a strong academic involvement, continues to support research that will lead to better estimates of the costs and benefits of possible actions to mitigate global climate change. New emphasis in improving the integrated assessment models is on including other greenhouse gases other than carbon dioxide, carbon sequestration, and international trade. The Information and Integration program stores, evaluates, and quality-assures a broad range of global environmental change data and disseminates these to the broad research community. Included is the Quality Systems Science Center for the tri-lateral (Mexico, United States, and Canada) North American Strategy for Troposheric Ozone (NARSTO), a public partnership for atmospheric research in support of air quality management. University scientists play key roles in this program.			
The Global Change Education Program supports DOE-related research in global environmental change for both undergraduate and graduate students, through the DOE Summer Undergraduate Research Experience (SURE), the DOE Graduate Research Environmental Fellowships (GREF), and collaboration with the NSF Significant Opportunities in Atmospheric Research and Science (SOARS) Program.	8,048	8,209	8,170
■ Congressional direction in FY 2000 for the Utton Transboundary Center.	0	1,405	0
Total, Human Interactions	8,048	9,614	8,170
SBIR/STTR			
■ In FY 1999 $2,800,000 and $169,000 were transferred to the SBIR and STTR programs respectively. The FY 2000 and FY 2001 amounts are the estimated requirements for the continuation of these programs.	0	3,386	3,376
Total, Environmental Processes	114,530	127,116	131,509

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Climate and Hydrology	
■ Increase in support of implementing model development for simulating multi-decade and multi-century environmental changes at regional resolution.	+4,117
■ Increase in support of connection of ARM data with carbon cycle research and continued development of improvements for climate models.	+948
■ ARM UAV continues at near FY 2000 level.	+31
Total, Climate and Hydrology	+5,096
Atmospheric and Carbon Cycle	
■ Continue Atmospheric Science programs at approximately same level of effort of FY 2000	-323
■ Increase support for studies to understand the biochemical processes and pathways linking carbon fixation and nitrogen cycling in marine microorganisms.	+446
■ Increase in support of expanding research at the carbon sequestration research centers	+1,947
■ Congressional direction in FY 2000 for the National Energy Laboratory in Hawaii.	-1,405
Total, Atmospheric and Carbon Cycle	+665
Ecological Processes	
■ Increase in support of Free Air Carbon Dioxide Enrichment experiments that continue at near FY 2000 level.	+86
Human Interactions	
■ Continue support for education at approximately same level as FY 2000	-39
■ Congressional direction in FY 2000 for the Utton Transboundary Center.	-1,405
Total, Human Interactions	-1,444
SBIR/STTR	
■ Decrease in SBIR/STTR.	-10
Total Funding Change, Environmental Processes	+4,393

Environmental Remediation

Mission Supporting Goals and Objectives

The research is primarily focused on gaining a better understanding of the fundamental biological, chemical, geological, and physical processes that must be marshaled for the development and advancement of new, effective, and efficient processes for the remediation and restoration of the Nation's nuclear weapons production sites. Priorities of this research are bioremediation and operation of the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL). Bioremediation activities are centered on the Natural and Accelerated Bioremediation Research (NABIR) program, a basic research program focused on determining the conditions under which bioremediation will be a reliable, efficient, and cost-effective technique. This subprogram also includes basic research in support of pollution prevention, sustainable technology development and other fundamental research to address problems of environmental contamination. Facility Operations supports the operation of the EMSL national user facility for basic research that will underpin safe and cost-effective environmental remediation methods and technologies and other environmental priorities. Unique EMSL facilities such as the Molecular Science Computing Facility, the High-Field Mass Spectrometry Facility, and the High-Field Magnetic Resonance Facility will be used by the external scientific community and EMSL scientists to conduct a wide variety of molecular-level environmental science research, including improved understanding of chemical reactions in DOE's underground storage tanks, movement of contaminants in subsurface groundwater and vadose zone sediments, and atmospheric chemical reactions that contribute to changes in the atmospheric radiative balance. In the NABIR program, research advances will continue to be made from pore to field scales in the Biogeochemical Dynamics element; on genes and proteins used in bioremediation through the Biomolecular Science and Engineering element; in non-destructive, real-time measurement techniques in the Assessment element; in overcoming physico-chemical impediments to bacterial mobility in the Acceleration element; on species interaction and response of microbial ecology to contamination in the Community Dynamics and Microbial Ecology element; and in understanding microbial processes for altering the chemical state of metallic and radionuclide contaminants through the Biotransformation and Biodegradation element. In analogy with the Ethical, Legal, and Social Implications component of the Human Genome Program, the Bioremediation and Its Societal Implications and Concerns component of NABIR will explore societal issues surrounding bioremediation research and promote open and two-way communication with affected stakeholders, avoiding dictating solutions. Research in the Systems Integration, Prediction, and Optimization element is being initiated to help define and develop an integrative model to aid collaboration and direction across research teams within the NABIR program. All NABIR elements and EMSL activities have a substantial involvement of academic scientists.

Performance Measures

- The first Field Research Center (FRC) for the Natural and Accelerated Bioremediation Research (NABIR) program will be selected at a DOE site in early calendar year 2000. Field site characterization will be completed and subsurface research at the FRC will be started during 2001, providing the fundamental knowledge for development of bioremediation methodologies for containment and clean-up of hazardous materials. NABIR research teams will be developed to build on the strengths of the individual NABIR projects and begin the process of integrating individual research efforts across the program elements, including the fundamental research in environmental and molecular sciences that underpins the development of bioremediation techniques for containing hazardous wastes and cleaning up contaminated DOE sites.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Bioremediation Research	31,234	31,129	27,093	-4,036	-13.0%
Clean Up Research............................	3,632	3,383	1,467	-1,916	-56.6%
Facility Operations	29,909	28,823	32,415	+3,592	+12.5%
Waste Management	0	0	1,200	+1,200	+100.0%
SBIR/STTR	0[a]	1,516	1,361	-155	-10.2%
Total, Environmental Remediation	64,775	64,851	63,536	-1,315	-2.0%

Detailed Program Justification

(dollars in thousands)

FY 1999	FY 2000	FY 2001

Bioremediation Research

- In NABIR, progress will be made in understanding the intrinsic bioremediation (natural attenuation) of DOE relevant metal and radionuclide contaminants, as well as manipulated, accelerated bioremediation using chemical amendments. Laboratory and field experiments (such as at the UMTRA sites) will be conducted to understand the fundamental mechanisms underlying chemical processes, complexation/transformation of contaminants, and to understand microbial transport. The number of field experiments at other sites will be reduced as the first Field Research Center is implemented. The Field Research Center is currently planned for Oak Ridge National Laboratory pending successful completion of a National Environmental Policy Act (NEPA) review. Field site characterization of the first NABIR Field Research Center will proceed and distribution of research samples to investigators will be initiated. Science elements in the NABIR program include fundamental research in the following subjects: a) Biotrans-formation and Biodegradation (microbiology to elucidate the mechanisms of biotransformation and biodegradation of complex

[a] Excludes $1,444,000 which has been transferred to the SBIR program and $86,000 which has been transferred to the STTR program.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
contaminant mixtures); b) Community Dynamics and Microbial Ecology (ecological processes and interactions of biotic and abiotic components of ecosystems to understand their influence on the degradation, persistence, mobility, and toxicity of mixed contaminants); c) Biomolecular Science and Engineering (molecular and structural biology to enhance our understanding of bioremediation and improve the efficacy of bioremedial organisms and identify novel remedial genes); d) Biogeochemical Dynamics (dynamic relationships among *in situ* geochemical, geological, hydrological, and microbial processes); e) Assessment (measuring and validating the biological and geochemical processes of bioremediation); f) Acceleration (flow and transport of nutrients and microorganisms, focused on developing effective methods for accelerating and optimizing bioremediation rates); and g) System Engineering, Integration, Prediction, and Optimization, (conceptual and quantitative methods for describing community dynamics, biotransformation, biodegradation, and biogeochemical dynamics processes in complex geologic systems). University scientists form the core of the NABIR science team that networks with the broader academic community as well as with scientists at other agencies.	25,299	25,173	21,113
■ General Plant Projects (GPP) funding is for minor new construction, other capital alterations and additions, and for buildings and utility systems such as replacing piping in 30 to 40-year old buildings, modifying and replacing roofs, and HVAC upgrades and replacements. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and in meeting its requirement for safe and reliable facilities operation. This subprogram includes landlord GPP funding for Pacific Northwest National Laboratory (PNNL) and for Oak Ridge Institute for Science and Education (ORISE). The total estimated cost of each GPP project will not exceed $5,000,000..	4,766	4,692	4,811
■ General Purpose Equipment (GPE) funding for general purpose equipment for PNNL and ORISE such as updated radiation detection monitors, information system computers and networks, and instrumentation that supports multi-purpose research............	1,169	1,264	1,169
Total, Bioremediation Research..	31,234	31,129	27,093

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Clean Up Research			
■ A modest program will be maintained to characterize the geologic, chemical, and physical properties that affect the rate and effectiveness of a variety of environmental remediation and waste-stream cleanup methods, including bioremediation.	3,632	3,383	1,467
Facility Operations: William R. Wiley Environmental Molecular Sciences Laboratory (EMSL)			
■ The EMSL is a national scientific user facility focused on conducting interdisciplinary, collaborative research in molecular-level environmental science. Operating funds are essential to allow the EMSL to operate as a user facility, and are used for maintenance of buildings and instruments, utilities, staff support for users, environment, safety and health compliance activities, and communications. With over 100 leading-edge instruments and computer systems, the EMSL annually supports approximately 600 users. University scientists form the core of the EMSL science team that networks with the broader academic community as well as with scientists at other agencies. EMSL users have access to unique instrumentation for environmental research, including the 512-processor, high performance computer system, a suite of nuclear magnetic resonance spectrometers ranging from 300 MHZ to 800 MHZ, a suite of mass spectrometers, including an 11.5 Tesla high performance mass spectrometer, laser desorption and ablation instrumentation, ultra-high vacuum scanning tunneling and atomic force microscopes, and controlled atmosphere environmental chambers.	27,933	26,842	27,426
■ Capital equipment support for the EMSL enables instrument modifications needed by collaborators and external users of the facility as well as the purchase of state-of-the-art instrumentation to keep EMSL capabilities at the leading edge of molecular-level scientific research. Additional capital equipment funds ($3,000,000) are requested to expand the user capabilities of EMSL to include high-throughput functional genomics and structural biology. This expansion will include acquisition of additional mass spectrometers and Nuclear Magnetic Resonance spectrometers (NMRs), including the first commercial prototype of a high throughput, 9.4 Tesla Fourier Transform Mass Spectrometer specifically built for proteomics studies	1,976	1,981	4,989
Total, Facility Operations	29,909	28,823	32,415

	(dollars in thousands) FY 1999	FY 2000	FY 2001
Waste Management			
■ Provides for packaging, shipment, and disposition of hazardous, radioactive, or mixed waste generated at Pacific Northwest National Laboratory in the course of normal operations. These activities were funded by Environmental Management prior to FY 2001.	0	0	1,200
SBIR/STTR			
■ In FY 1999, $1,444,000 and $86,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts are the estimated requirements for the continuation of these programs.	0	1,516	1,361
Total, Environmental Remediation	64,775	64,851	63,536

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Bioremediation Research	
■ Funding for research at distributed field research sites is decreased to focus field research at NABIR Field Research sites.	-4,060
■ Increase in General Plant Projects that continue at near FY 2000 level.	+119
■ Decrease in General Purpose Equipment that continues at near FY 2000 level.	-95
Total, Bioremediation Research	-4,036
Cleanup Research	
■ Cleanup research on ex-situ approaches, which are now highly developed, is being reduced to focus on more challenging problems of in situ cleanup	-1,916
Facility Operations	
■ Increase in support of science conducted at the national user facility, EMSL.	+584
■ Increase in capital equipment budget for EMSL.	+3,008
Total, EMSL	+3,592

	FY 2001 vs. FY 2000 ($000)
Waste Management	
■ Increase provides for packaging, shipment, and disposition of hazardous, radioactive, or mixed wastes generated at the Pacific Northwest National Laboratory in the course of normal operations.	+1,200
SBIR/STTR	
■ SBIR/STTR decrease due to decrease in research funding.	-155
Total Funding Change, Environmental Remediation	-1,315

Medical Applications and Measurement Science

Mission Supporting Goals and Objectives

The Medical Applications category supports research to develop beneficial applications of nuclear and other energy-related technologies for medical diagnosis and treatment. The research is directed at discovering new applications of radiotracer agents for medical research as well as for clinical diagnosis and therapy. A major emphasis is placed on application of the latest concepts and developments in genomics, structural biology, computational biology, and instrumentation. Much of the research seeks breakthroughs in noninvasive imaging technologies such as positron emission tomography. Biomedical engineering is an area of emphasis in the medical applications program. Research is directed to fundamental studies in artificial organs, biological and chemical sensors, imaging, lasers, informatics and other areas of technical expertise in the DOE laboratories.

The Measurement Science category focuses on research in analytical chemistry to develop new instrumentation to meet the needs of the environmental and life sciences research programs of the Biological and Environmental Research program. Research is also supported that will meet needs for new instrumentation to characterize contaminated environments in support of the Department's environmental cleanup program.

The Medical Applications and the Measurement Science subprogram has a substantial involvement of academic scientists.

Performance Measures

- Within the Medical Applications category, BER will initiate exploratory research to develop new messenger RNA (mRNA) based radiotracer technologies for imaging gene expression in animals in real time.

Funding Schedule

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Medical Applications	67,362	64,100	51,465	-12,635	-19.7%
Measurement Science.........................	5,844	4,619	5,849	+1,230	+26.6%
SBIR/STTR	0[a]	1,623	1,495	-128	-7.9%
Total, Medical Applications and Measurement Science.........................	73,206	70,342	58,809	-11,533	-16.4%

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Medical Applications			
■ Complete patient follow-up of all patients treated in human clinical trials of boron neutron capture therapy (BNCT) at Brookhaven National Laboratory and Massachusetts Institute of Technology to assess the maximum safe dosages of boron compound and neutron radiation. This is a collaborative program of university and laboratory scientists. Capital equipment funds will be used to support research on an accelerator-based facility for BNCT as an alternative to the use of nuclear reactors.	10,769	11,290	10,795

■ Develop new approaches to radiopharmaceutical design and synthesis using concepts from genomics as well as computational biology and structural biology. Complete research into radiolabeling of monoclonal antibodies for cancer diagnosis and therapy. Evaluate the clinical potential of real-time imaging of genes at work in cells, tissues, and whole organisms, including people. This information will have applications ranging from understanding the development of a disease to the efficacy of treatments for the disease. Continue to emphasize development of techniques for the simultaneous use of multiple radiotracers to study physiological processes. Additional funding will be used to support new, cutting edge research on imaging gene expression and developing new approaches to radiopharmaceutical design and synthesis. The development of technology to image gene expression <u>in cells and organs</u> using mRNA-based radiotracer technology will strongly impact developmental biology and

[a] Excludes $1,883,000 which has been transferred to the SBIR program and $113,000 which has been transferred to the STTR program.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
genome and medical sciences. In FY 2001, $5,841,000 is included to develop facilities and infrastructure at the University of South Carolina School of Public Health. This will support research to improve the health and environmental quality of communities served by DOE facilities; train potential new DOE employees and re-train current employees in public health and environmental health sciences using distance-based education modalities; and employ energy efficient design and construction techniques that serve as a model for future academic public health facilities.	19,766	20,938	30,445
■ Develop new concepts in multimodal imaging systems for study of human brain function and complete evaluation of the combination of nuclear medicine imaging systems with magnetic resonance imaging. Research to develop imaging instrumentation and transfer of relevant technology into clinical medicine. Capital equipment funds are provided in support of development of new instrumentation such as a PET camera for small animal imaging. Additional funding will also be used to support research in brain imaging. Additional funding will be used to develop a research program at the National Laboratories in biomedical engineering that capitalizes on their unique resources, and expertise in the biological, physical, chemical and engineering sciences to develop new research opportunities for technological advancement related to human health. The program will emphasize material sciences, sensors, tissue engineering, spectroscopy, informatics, and micro-fabricated machines. It will advance fundamental concepts, create knowledge from the molecular to the organ systems level, and develop innovative biologies, materials, processes, implants, devices, and informatics systems to be used for the prevention, diagnosis, and treatment of disease and for improving health care in the Nation. The programs will depend on critical collaboration with university scientists.	5,294	4,415	10,225
■ Congressional direction in FY 1999 for Gallo Prostate Cancer Research and Treatment Center, City of Hope National Medical Center, National Foundation for Functional Brain Imaging, State University of New York - Stony Brook, University of California – Davis, University of Alabama, New Mexico Highlands University, West Virginia National Education and Technology Center and the University of South Carolina Medical Center.	31,533	0	0

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
■ Congressional direction in FY 2000 for Gallo Institute of the Cancer Institute of New Jersey, City of Hope National Medical Center, National Foundation for Brain Imaging, University of Missouri Research Reactor, North Shore Long Island Jewish Health System, Burbank Hospital Regional Center, Midwest Proton Radiation Institute, Medical University of South Carolina Cancer Research Center, Center for Research on Aging at Rush Presbyterian St. Lukes Medical Center, University of Nevada Las Vegas Cancer Complex, Science Center at Creighton University, and the West Virginia National Education and Technology Center.	0	27,457	0
Total, Medical Applications	67,362	64,100	51,465
Measurement Science			
■ Complete research into new sensor instrumentation for characterization of chemical composition of contaminated subsurface environments in support of the Department's environmental cleanup efforts of highly radioactive chemical wastes. Continue research into new imaging instrumentation for life sciences and biomedical sensors applications. Capital equipment funds are provided for components needed for research into new instrumentation. Continue research in medical applications of laser technology at the National Laboratories and at universities. Additional funding will support the lasers in medicine program and imaging instrumentation.	5,844	4,619	5,849
SBIR/STTR			
■ In FY 1999, $1,883,000 and $113,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts are the estimated requirements for the continuation of these programs.	0	1,623	1,495
Total, Medical Applications and Measurement Science	73,206	70,342	58,809

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Medical Applications	
■ Reduction in BNCT research that continues at near FY 2000 level to follow up all patients treated during trials.	-495
■ Increase in new research to image the expression of genes in cells, tissues, and whole organisms, a capability that will dramatically impact much of biology and medical sciences. Also, includes an increase of $5,841,000 to develop infrastructure at the University of South Carolina School of Public Health.	+9,507
■ Increase in biomedical engineering research that bridges the gap between molecules and organ systems by developing new innovative biologics, materials, processes, implants, devices, and informatics systems for use in medicine ($5,000,000); and increase in nuclear medicine imaging research on multimodal systems, including brain imaging, to understand organ function ($810,000)	+5,810
■ Congressional direction in FY 2000 for Gallo Institute of the Cancer Institute of New Jersey, City of Hope National Medical Center, National Foundation for Brain Imaging, University of Missouri Research Reactor, North Shore Long Island Jewish Health System, Burbank Hospital Regional Center, Midwest Proton Radiation Institute, Medical University of South Carolina's Cancer Research Center, Center for Research on Aging at Rush Presbyterian St. Lukes Medical Center, University of Nevada Las Vegas Cancer Complex, Science Center at Creighton University, and the West Virginia National Education and Technology Center.	-27,457
Total Funding Change, Medical Applications	-12,635
Measurement Science	
■ Increase provides for research in the medical applications of laser science and technology.	+1,230
SBIR/STTR	
■ Decrease in SBIR/STTR.	-128
Total Funding Change, Medical Applications and Measurement Science	-11,533

Construction

Mission Supporting Goals and Objectives

Construction is needed to support the research under the Biological and Environmental Research Program (BER) program. Cutting-edge basic research requires that state-of-the-art facilities be built or existing facilities modified to meet unique BER requirements.

Funding Schedule

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Construction	0	0	2,500	+2,500	+100.0%
Total, Construction	0	0	2,500	+2,500	+100.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Construction			
■ The FY 2001 requested budget authority for the Laboratory for Comparative and Functional Genomics at Oak Ridge National Laboratory will provide a modern gene function research facility to support DOE research programs and provide protection for the genetic mutant mouse lines created during the past 50 years. This new facility will replace a 50-year old animal facility with rapidly escalating maintenance costs still in use at Oak Ridge.	0	0	2,500
Total, Construction	0	0	2,500

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Construction	
■ Begin construction of the Laboratory for Comparative and Functional Genomics.	+2,500

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
General Plant Projects	4,766	4,692	7,811	+3,119	+66.5%
Capital Equipment	22,116	11,635	27,650	+16,015	+137.6%
Total Capital Operating Expenses	26,882	16,327	35,461	+19,134	+117.2%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1999	FY 2000	FY 2001	Unapprop-riated Balance
01-E-300, Laboratory for Comparative and Functional Genomics, ORNL	13,900	0	0	0	2,500	11,400
Total, Construction		0	0	0	2,500	11,400

Major Items of Equipment (TEC $2 million or greater)

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1999	FY 2000	FY 2001	Acceptance Date
DNA Repair Protein Complex Beamline	4,500	0	0	0	4,500	FY 2001
Total, Major Items of Equipment		0	0	0	4,500	

01-E-300, Laboratory for Comparative and Functional Genomics, Oak Ridge National Laboratory, Oak Ridge, Tennessee

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 2001 Budget Request *(Preliminary Estimate)*	1Q2001	3Q2001	3Q2001	1Q2004	13,900	14,420

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2001	2,500	2,500	2,175
2002	10,000	10,000	6,980
2003	1,400	1,400	4,550
2004	0	0	195

3. Project Description, Justification and Scope

The Laboratory for Comparative and Functional Genomics (LCFG) will provide a modern gene function research facility to support Department of Energy research programs and provide protection for the genetic mutant mouse lines created during the past 50 years. The LCFG will replace the deteriorated mouse housing-facility located at the Y-12 Weapons Plant on the Oak Ridge Reservation to meet these programmatic needs.

The current Biology facilities are fifty years old and the buildings and building systems are in need of major upgrades which include asbestos abatement, roof replacement, HVAC replacement, underground utility system replacement, electrical systems upgrade, and exterior repairs to the building. Animal care accreditation depends on improving the housing conditions. The LCFG will provide cost-effective housing for the experimental animals that are vital to the next phase of the Genome program. It will be designed for efficient utilization of space and will be energy efficient and easy to maintain. It will accommodate the entire DOE live mutant mouse colony in Oak Ridge, which will be reduced in size by utilizing cryogenic preservation technology. The facility will be designed to permit the establishment of specific pathogen free colonies of mice.

The facility will be a single story building of approximately 32,000 sq.ft. comprised of four functional areas: support, animal housing, quarantine and laboratory support. The heating, ventilation and air-conditioning system will utilize 100% fresh air to achieve 10-15 air changes per hour and maintain temperatures between 68EF and 74EF with humidity levels of 40% to 60%. The system will be capable of maintaining +/- 2EF control in each animal housing room including the quarantine area. The lighting system will be timer controlled with variable intensity level between 130-325 lux. Sound levels will be maintained below 85 decibels. The internal water system will use reverse osmosis or special chlorination treatment to ensure adequate water chemistry. Floor, walls and ceilings will be constructed of durable, moisture-proof, fire-resistant, seamless materials to allow the highest possible levels of sanitation. Non-toxic paints and glazes will be used within the facility. The building will be equipped with silent fire alarm systems.

The building will be equipped with two tunnel washers, two rack washers, two pass-through autoclaves and two bulk autoclaves, a bedding dispenser, bedding disposal system and ventilated animal cage systems equipped with automatic watering. The HVAC system will include a 24-hour monitoring system. Other equipment includes slotted hood vents, down draft tables and surgical lighting in the laboratory support area to support animal procedures.

Site preparation will consist of clearing, grading, and excavating for the new structure; extension of access streets to the site; and landscaping and seeding. Outside utilities will consist of extending the required utilities from the building to the closest, and an adequately sized supply source. Utilities will include steam, sanitary sewers, potable and fire protection water, natural gas, and electricity.

Obligations for FY 2001 will be used to award the Engineer/Procure/Construct Contract (EPCC) with sufficient funds to accomplish the detail design, initiate construction, and to order long-lead items. First year funding will also support project management and inspection of construction.

The researchers and animals are currently housed in facilities at the East end of the Y-12 Weapons Plant. Most of the buildings that have been used for biology were constructed in the late 1940s or early 1950s for other purposes. The building housing the animals has deteriorated with age and cannot be maintained cost effectively and the building systems need to be upgraded to assure continued compliance with accreditation standards for animal research facilities. In addition to being expensive to operate and maintain, the existing facility does not provide a barrier maintenance facility for maintaining immune deficit and other lines of mice that require a pathogen-free environment.

The principle programmatic reasons for constructing the new facility are to ensure adequate, cost effective housing for the national resource embodied in the mutant mouse colony to support the next phase of the Genome Program - the identification of gene function.

In addition, benefits include:

- Enabling the DOE Mammalian Genetics User Facility to more effectively support the national research community and DOE researchers at other institutions.
- Providing substantially more effective collaboration between the Life Sciences Division and other Oak Ridge National Laboratory (ORNL) facilities and Divisions such as Environmental Sciences, Chemical and Analytical Sciences, Solid State, and Computing and Mathematical Sciences Divisions as well as the Center for Computational Sciences.
- Enhancing ORNL's ability to attract first rate young scientists to facilities that represent state-of-the-art laboratories that are cost effective in operation and efficient in the conduct of biological research.
- Facilitating the access for visiting scientists worldwide by eliminating the restrictions stemming from the close proximity of a high-security weapons plant.
- Developing facilities that offer unique resources of the organization and the world-class capabilities of the staff.
- Continuing the contribution to higher education via administration of and participation in the University of Tennessee - Oak Ridge Graduate School of Biomedical Sciences.

4. Details of Cost Estimate [a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design Costs (Design, Drawings, and Specifications)	465	N/A
Design Management Costs (0.3% of TEC)	40	N/A
Project Management Costs (0.2% of TEC)	30	N/A
Total, Design Costs (3.8% of TEC)	535	
Construction Phase		
Buildings	7,815	N/A
Utilities	140	N/A
Standard Equipment	3,530	N/A
Inspection, design and project liaison, testing, checkouts and Acceptance	250	N/A
Construction Management (0.6% of TEC)	80	N/A
Project Management (1.2% of TEC)	160	N/A
Total, Construction Costs	11,975	
Contingencies (10% of TEC)		
Design Phase	45	N/A
Construction Phase	1,345	N/A
Total, Contingencies (10% of TEC)	1,390	
Total Line Item Costs (TEC)	13,900	N/A

5. Method of Performance

Detail design, procurement and construction will be accomplished by a fixed price Engineer/Procure/ Construct Contractor (EPCC).

[a] The cost estimate is based on a conceptual design completed in April 1998. The DOE Headquarters escalation rates were used as appropriate over the project life.

6. Schedule of Project Funding

	(dollars in thousands)				
	Prior Years	FY 2000	FY 2001	Outyears	Total
Project Cost					
Facility Cost					
Design	0	0	580	0	580
Construction	0	0	1,595	11,725	13,320
Total, Line item TEC	0	0	2,175	11,725	13,900
Other project costs					
Conceptual design costs [a]	20	0	0	0	20
NEPA documentation costs [b]	0	15	0	0	15
Other project related costs [c]	0	485	0	0	485
Total, Other Project Costs	20	500	0	0	520
Total Project Cost (TPC)	20	500	2,175	11,725	14,420

[a] A conceptual design report (CDR) was completed in April 1998 at a cost of $20,000.

[b] NEPA for this project is expected to require a NEPA Categorical Exclusion Determination (CXD). Estimated cost is $15,000.

[c] Soil borings and other sampling and documentation associated with site characterization to be completed in FY 2000 at an estimated cost of $60,000. A detailed requirements document (including Design Criteria) and Engineer/ Procure/Construct Contractor (EPCC) selection activities will be completed in FY 2000 at an estimated cost of $340,000. Technical and project management support through FY 2000 are estimated at a cost of $85,000.

7. Related Annual Funding Requirements

(FY 2004 dollars in thousands)

	Current Estimate	Previous Estimate
Annual facility operating costs[a]	675	N/A
Facility maintenance and repair costs[b]	130	N/A
Programmatic operating expenses directly related to the facility[c]	740	N/A
Capital equipment not related to construction but related to the programmatic effort in the facility[d]	205	N/A
Utility costs	510	N/A
Other costs[e]	205	N/A
Total related annual funding	2,465	N/A

[a] This includes janitorial and other miscellaneous support services. Approximately five staff years of effort will be required to provide these services. This is approximately $360,000 less than the cost for operating the existing facility. The savings result from having a modern facility with a more functional design.

[b] The FY 1998 facility maintenance and utility cost for the existing ORNL animal housing facilities totaled approximately $1,350,000. Based on experience with functionally comparable buildings at the ORNL site with energy conservation features incorporated in the construction, the estimated maintenance and utilities cost for the proposed facility are approximately $130,000 for maintenance and $510,000 for utilities. Thus, the savings in operating funds is estimated to be nearly $710,000, per year.

[c] The FY 1998 programmatic operating expenses of the existing animal housing facilities were approximately $740,000. This includes funding for animal care support personnel. This level of funding will not increase as a result of the proposed relocation of facilities.

[d] The conduct of modern biological research by the LCFG such as that involved in the Human Genome Project and Structural Biology requires the periodic purchase of capital scientific equipment. Recurring annual cost of capital equipment is approximately $205,000.

[e] The estimated expenditures for programmatic related maintenance are approximately $205,000 per year. This includes funding for three maintenance personnel to perform programmatic related maintenance. The relocation to the proposed facility will result in an estimated savings of approximately $50,000 per year. The new animal support equipment will require a smaller portion of the operating budget for maintenance.

8. Design and Construction of Federal Facilities

All DOE facilities are designed and constructed in accordance with applicable Public Laws, Executive Orders, OMB Circulars, Federal Property Management Regulations, and DOE Orders. The total estimated cost of the project includes the cost of measures necessary to assure compliance with Executive Order 12088, “Federal Compliance with Pollution Control Standards”; section 19 of the Occupational Safety and Health Act of 1970, the provisions of Executive Order 12196, and the related Safety and Health provisions for Federal Employees (CFR Title 29, Chapter XVII, Part 1960); and the Architectural Barriers Act, Public Law 90-480, and implementing instructions in 41 CFR 101-19.6. This project includes the construction of new buildings and/or building additions; therefore, a review of the GSA Inventory of Federal Scientific Laboratories is required. The project will be located in an area not subject to flooding determined in accordance with the Executive Order 11988.

Basic Energy Sciences

Program Mission

The MISSION of the Basic Energy Sciences (BES) program is to foster and support fundamental research in the natural sciences and engineering to provide a basis for new and improved energy technologies and for understanding and mitigating the environmental impacts of energy use. As part of its mission, BES plans, constructs, and operates major scientific user facilities to serve researchers at universities, national laboratories, and industrial laboratories.

The high quality of the research in this program is regularly evaluated through the use of merit based peer review and scientific advisory committees.

Program Goals

- Maintain U.S. world leadership in areas of the natural sciences and engineering that are relevant to energy resources, production, conversion, and efficiency and to the mitigation of the adverse impacts of energy production and use;
- Provide world-class scientific user facilities for the Nation;
- Foster and support the discovery, dissemination, and integration of the results of fundamental, innovative research; and
- Act as a steward of human resources, essential scientific disciplines, institutions, and premier scientific user facilities.

Program Objectives

- *Obtain major new fundamental knowledge.* - Foster and support fundamental, innovative, peer-reviewed research to create new knowledge in areas important to the BES mission, i.e., in materials sciences, chemical sciences, geosciences, plant and microbial biosciences, and engineering sciences.
- *Plan, construct, and operate premier national scientific user facilities* – Provide facilities for materials research and related disciplines to serve researchers at universities, national laboratories, and industrial laboratories, thus enabling the acquisition of new scientific knowledge. These scientific facilities include synchrotron radiation light sources, high-flux neutron sources, electron-beam microcharacterization centers, and specialized facilities such as the Combustion Research Facility. Encourage and facilitate the use of these facilities in areas important to BES activities and also in areas that extend beyond the scope of BES activities, such as structural biology, environmental science, medical imaging, rational drug design, micromachining, and industrial technologies.
- *Support the missions of the Department of Energy (DOE).* - Promote the transfer of the results of basic research to contribute to DOE missions in areas of energy efficiency, renewable energy resources, improved use of fossil fuels, reduced environmental impacts of energy production and use, science-based stockpile stewardship, and future energy sources.

- *Establish and maintain stable, essential research communities and institutions.* - Steward important research communities and institutions in order to respond quickly and appropriately to scientific opportunity and mission need. For example, BES serves as the Nation's primary or sole supporter of such subdisciplines as heavy element chemistry, natural and artificial solar energy conversion, catalysis, organometallic chemistry, combustion-related science including gas-phase kinetics and reaction dynamics, separations science, neutron science, radiation chemistry, and radiation effects in materials. Some of these research activities exist primarily in the DOE laboratories, e.g., heavy element chemistry; others exist both in DOE laboratories and in universities. In all cases, participation by students, postdoctoral research associates, and young faculty and staff is an imperative to ensure continuation and intellectual growth of the research communities.

Performance Measures

BES, which is prototypical of a large, diverse research program existing within a mission agency, measures performance in four ways: (1) peer review; (2) indicators or metrics (i.e., things that can be counted); (3) customer evaluation and stakeholder input; and (4) qualitative assessments, which might include historical retrospectives and annual program highlights. A number of activities that might be considered essential or "foundation" performance measurement activities are already in place in BES. Indeed, some have been ongoing for many years. Paramount among these is peer review of all research activities.

During FY 1998, BES instituted several changes in the way performance measurement is accomplished to better quantify it. First, BES formalized the peer review process for activities at the DOE laboratories. Although research at the laboratories had long been peer reviewed, BES codified that process using a process analogous to that described in 10 CFR 605 for the university grant program. Second, in FY 1999, BES established baselines for all performance indicators for each scientific user facility using a new survey tool. This survey tool, developed in FY 1997 in collaboration with the facility directors and the facility user coordinators, is completed annually by all BES facilities. An integral part of the survey tool is an assessment of user satisfaction. Third, BES began formal peer reviews of its major scientific user facilities to assess, in the aggregate, the scientific output and, to the extent possible, the outcomes of facilities. Recent and forthcoming reviews conducted by the Basic Energy Advisory Committee (BESAC) include: (1) the 1997 review of the four synchrotron radiation light sources, "Synchrotron Radiation Sources and Science," (2) the 1998 review of the "High-Flux Isotope Reactor Upgrade and User Program," (3) the 1999 review of R&D requirements for "Novel Coherent Light Sources," (4) the 1999 review of the four BES electron beam microcharacterization centers, which will be presented to BESAC in February 2000, (5) a forthcoming review of the Advanced Light Source that is planned for February 2000 and which will be presented to BESAC in February 2000, (6) a forthcoming review of the Intense Pulsed Neutron Source and the Manuel Lujan Jr., Neutron Scattering Center that is planned for the summer of 2000, and (7) a review of neutron scattering activities in the context of the permanent closure of the High Flux Beam Reactor, which will be presented to BESAC in February 2000.

Performance measurement helps determine both the distribution of activities supported within the BES program and the individual projects supported within each activity. The funding level for each activity is derived by weighing a number of additional factors including (1) mission need as described by the BES program and the Office of Science (SC) mission statements and the SC strategic plan; (2) scientific opportunity as determined, in part, by proposal pressure and by scientific workshops; (3) the results of international benchmarking activities of entire fields or subfields such as those performed by the National Academy of Sciences; (4) connections with other BES and SC supported work; (5) connections with needs expressed by the DOE technology offices and by energy-intensive industries; (6) program balance including considerations of activities funded by non-BES sources; and (7) budgetary constraints.

In FY 2001, (1) meet the cost and schedule milestones for upgrade and construction of scientific user facilities, including the construction of the Spallation Neutron Source; the cost and schedule will be kept within 10 percent of cost and schedule baselines as reflected by regular external independent reviews of project management cost and schedule; (2) maintain and operate user facilities so that the unscheduled downtime, on average, is less than 10 percent of the total scheduled operating time, as reported to Headquarters by facilities at the end of each fiscal year; (3) all research projects will undergo regular peer review and merit evaluation based on procedures set down in 10 CFR 605 for the extramural grant program and under a similar modified process for the laboratory programs and scientific user facilities; (4) new projects will be selected by peer review and merit evaluation; and (5) research performed by investigators in universities and DOE laboratories will continue to be recognized as outstanding during rigorous peer review and through the awards and accolades of the broader science community and others that use our results as reflected by peer review comments and annual awards data collected by the program.

Prizes, Awards, and Honors

Each fiscal year, principal investigators funded by BES win dozens of major prizes and awards sponsored by professional societies, distinguished foundations, and universities. Paramount among the honors are the four Nobel Prizes awarded to BES principal investigators over the past five years. In FY 1999, many were inducted as members in organizations such as the National Academy of Sciences, the National Academy of Engineering, and other professional societies.

Selected major prizes and awards for FY 1999 include:

From the ASM International (formerly the American Society of Metals) — Materials Science Research Silver Medal

From the American Academy of Microbiology — Proctor & Gamble Award in Applied and Environmental Microbiology

From the American Ceramic Society — the George W. Morey Award; the Richard M. Fulrath Award

From the American Chemical Society — the Priestly Medal; the Arthur C. Cope Scholar Award; Award in Inorganic Chemistry; Buck-Whitney Medal; Charles Holmes Herty Medal; Claude S. Hudson Award in Carbonhydrate Chemistry; George A. Olah Award in Hydrocarbon or Petroleum; James Flack Norris Award in Physical Organic Chemistry; Award for Distinguished Service

From the American Geophysical Union — the Bowen Award

From the American Institute of Chemical Engineers — the Research Achievement Award

From the American Physical Society — the David Adler Lectureship Award; the Davisson-Germer Prize; two James C. McGroddy Prizes; Outstanding Doctoral Thesis Research in Beam Physics; Roger Revelle Medal; the Nottingham Prize

From the U.S. Department of Commerce — the National Medal of Technology

From the Electrochemical Society — the Carl Wagner Memorial Award; the David C. Grahame Award

From the Faraday Society in England — the Bourke Lecturer Award

From the Federal Laboratory Consortium — the Federal Laboratory Consortium Award

From the Geological Society of America — the Arthur L. Day Medal

From the Institute of Liquid Atomization and Spray Systems — the Harold Simmons Award

From the International Society for Measurement and Control — two Arnold O. Beckerman Founder Awards

From the International Society for Optical Engineering — the Harold E. Edgerton Prize

From the International Institute of Welding — U.S. Representation for Study Group on Physics of Welding

From the MacArthur Foundation — the John D. Catherine T. MacArthur Foundation Fellowship

From the Materials Research Society — the Medal for Significant Achievements

From the North American Catalysis Society — the Robert Burwell Lectureship Award; the Paul H. Emmett Award

From R&D Magazine — R&D 100 Awards for:

- Direct Injection High Efficiency Nebulizer, a device for improved introduction of liquid samples into an inductively coupled plasma for subsequent analysis by emission or mass spectrometry
- Acoustic Stirling Cycle Refrigerator, a new heat engine that efficiently converts heat to intense acoustic power in a simple device that comprises only pipes and conventional heat exchangers and has no moving parts
- Gregar Extractor, a more efficient, more reliable, and often faster device for solvent-based chemical extraction from solid samples
- Molecular Sciences Software Suite, the first general-purpose software that allows chemists to easily use high-performance, massively parallel computers for a wide range of applications
- Rolling Assisted Biaxially Textured Substrates, or RABiTS, technology for the manufacture of long lengths of ultra-high-performance superconducting wires necessary for a wide range of high-temperature superconductors.

From the Royal Society of Chemistry — the Centenary Medal

From the Society for Technology Transfer — two Lang Rosen Awards for an Innovative New Approach to R&D Assessment

From the Society of Imaging Science and Technology — the Kosar Memorial Award

One principal investigator received the Presidential Early Career Award for Scientists and Engineers, three were inducted into the National Academy of Sciences, and three were inducted into the National Academy of Engineering. Principal investigators were advanced to fellowship in the following societies and organizations: three in the American Ceramic Society; eleven in the American Physical Society; four in ASM International (formerly the American Society for Metals); two in the Electrochemical Society; four in the Optical Society of America; four in the Japan Society for the Promotion of Science; and one each in the American Academy of Arts and Sciences; the American Association for the Advancement of Science; Institute of Materials of London, Institute of Physics, the American Welding Society, the Metallurgical Society, the International Women's Forum Leadership Program, the American Academy of Arts and Sciences, and the Third World Academy of Sciences.

Finally, principal investigators served in numerous elected offices including: President, International Society of Electrochemistry; President, American Ceramic Society; Vice Chair, Division of Materials Physics, American Physical Society; two Vice Chairs, American Physical Society; Chair, Council of Fellows, ASM International; Director, Photobiology Foundation; Director, Microbeam Analysis Society; and President, Association of Women in Mathematics.

Significant Accomplishments and Program Shifts

The BES program is one of the Nation's major sponsors of fundamental research in broad areas of materials sciences, chemical sciences, geosciences, plant and microbial sciences, and engineering sciences. The program encompasses more than 2,400 researchers in nearly 200 institutions and 16 of the Nation's outstanding user facilities. The BES program funds research at 149 colleges/universities located in 48 states. The inclusion of research activities at this large number of academic institutions is a vital part of the program. These scientists are funded through individual peer-reviewed grants and as members of peer-reviewed research teams involving investigators from both national laboratories and universities. In addition, university-based scientists are among the principal users of the BES user facilities.

The BES program is the premier sponsor of condensed matter and materials physics in the U.S. Furthermore, its chemical sciences program is the U.S. leader in research in homogeneous and heterogeneous catalysis, photchemistry and radiation chemistry, gas-phase chemical dynamics, and separations and analysis. The chemical sciences program is the only program in the U.S. addressing heavy element chemistry, including today's issues of heavy element chemistry in the environment; this aspect of the program traces its roots to the 1940s Manhattan Project. Finally, the stunning portfolio of research and scientific user facilities devoted to visualizing, characterizing, and controlling the nanoworld – from atoms and molecules to bulk materials – makes the BES program unique in the world.

The BES program has taken a leadership role in defining and addressing the 21st century challenges facing the physical and biological sciences – from understanding collective effects in materials to designing new materials atom by atom and, finally, to developing functional materials. Functional materials are those with the ability to self assemble, self repair, sense, respond, and evolve in order to provide functional properties – optical, mechanical, catalytic, electrical, and tribological. Envisioning and creating these materials is the coming challenge for the disciplines of materials sciences, chemistry, physics, and biology.

Presented below are program accomplishments from FY 1999. The selected program highlights are representative of the broad range of studies supported in the BES program. These highlights demonstrate the discovery of new knowledge, the rapidity with which such new knowledge can be incorporated into other scientific disciplines and into the commercial sector, and the great potential of new knowledge for future impacts in energy production and use. Following are discussions of scientific facilities and new program directions for FY 2001.

Selected FY 1999 Scientific Highlights/Accomplishments

- In FY 1999, the following performance goal was fully met: Begin Title I design activities, initiate subcontracts and long-lead procurements and continue R&D work necessary to begin construction activities of the Spallation Neutron Source.
- **Serendipitous Applications of Research in the Physical Sciences to the Life Sciences.** It has long been recognized that tools and concepts developed in the physical sciences can revolutionize the life sciences. One need only consider the impact of x-ray synchrotron radiation and MAD (multiple wavelength anomalous diffraction) phasing on macromolecular crystallography; both were developed within the BES program. In FY 1999, many of the annual BES program highlights illustrate the rapidity with which advances in the physical sciences are impacting the life sciences. Two examples are given here. First, new techniques of nuclear magnetic resonance (NMR) are being used to study the molecular structures of solid protein deposits implicated in brain diseases such as Alzheimer's Disease and BSE (Mad Cow Disease); both diseases involve the transformation of normal, soluble proteins in the brain (whose structure is known) into fibers of insoluble plaque (whose structure is largely unknown). Second, a nano-laser device has been shown to have the potential to quickly identify a cell population that has begun the rapid protein synthesis and mitosis characteristic of cancerous cell proliferation. Pathologists currently rely on microscopic examination of cell morphology using century-old staining methods that are labor-intensive, time-consuming, and frequently in error.

Materials Sciences Subprogram

- **Seashell Provides Key to Strong Composites.** Mollusk shells have evolved over millions of years to provide hard, strong, tough shelters for fragile occupants. These outstanding mechanical properties derive from a laminated construction of alternating layers of biopolymer – a biologically produced rubber – and calcium carbonate, commonly known as chalk. It has been recognized for decades that materials with alternating hard and soft layers absorb energy and impede cracking. Unfortunately, it has proven difficult to transcribe seashell-like designs into manufacturable materials. Now, a rapid, efficient self-assembly process has been developed for making “nanocomposite” materials that mimic the construction of seashells. This process can be generalized and should lead to materials with unprecedented mechanical properties.

- **Imaging Fluid Distribution and Flow in Materials.** Dramatic pictures of the distribution and flow of fluids inside intact objects and porous solid materials have been obtained by magnetic resonance imaging (MRI) and nuclear magnetic resonance (NMR). The ability to observe such images and spectra results from the use of noble gases, particularly xenon, magnetically polarized by means of a laser. This advance makes possible the observation of MRI pictures and NMR spectra in ultralow magnetic fields. The technique produces brilliant pictures (up to a millionfold increase in brightness) and provides a new capability for noninvasive investigation of flow and transport. The images and spectra allow the characterization of atomic distribution and flow from the smallest scale of nanotubes to the largest scale of macroscopic samples. The flow of fluids through solid materials is a crucial component of many industrial processes from the catalytic conversion of petroleum to the containment of toxic environmental agents. These advances will eliminate the need for high magnetic fields in some applications of MRI and NMR, a welcomed event given the cost, bulk, hazard, and lack of portability of the magnets used in contemporary instrumentation.

- **New Fullerene Species Synthesized - Stickyball, C_{36}.** A new fullerene species, C_{36}, has been synthesized and produced in bulk quantities for the first time. Fullerenes or "buckyballs" are hollow clusters of carbon atoms. They have been studied extensively since the Nobel prize-winning discovery of C_{60} in 1985 (supported by BES). C_{36} is the smallest fullerene discovered to date and is characterized by unusual and potentially very useful properties. For example, in contrast to C_{60} molecules, which interact only very weakly with one another, C_{36} molecules stick together – hence the nickname "stickyballs." The lower fullerenes, such as C_{36} are predicted to have more highly strained carbon bonds, resulting in exciting properties for those molecules such as very high chemical reactivity and high temperature superconductivity. The synthesis of C_{36} is particularly significant, because previously it was believed that any fullerene smaller than C_{60} would be too unstable to isolate in bulk.

- **Seeing Clearly Now.** Using a new imaging technique called Z-contrast imaging, researchers have achieved the highest resolution electron microscope image of a crystal structure ever recorded, resolving adjacent columns of silicon atoms separated by a scant 0.78 angstroms (3 billionths of an inch). Better resolution enables scientists to see and understand important details they had not been able to see before. This technique also offers both high spatial resolution and the ability to distinguish different kinds of atoms. The precise atomic-scale structure of a material controls the performance of materials for semiconductor devices, superconductors, and a host of other applications. Combined with improved electron imaging optics currently under development, this result promises to revolutionize the atomic-scale understanding of materials.

- **New Family of Bulk Ferromagnetic Metallic Glasses for Energy Efficient Motors and Transformers.** New rules for designing alloys have been developed that enable the creation of a family of bulk metallic glass alloys. These alloys exhibit outstanding ferromagnetic behavior with virtually no energy loss. These new alloys are at least 65 percent iron plus contain up to seven other elements. Until now, such alloys could only be produced as thin foils. Commercial transformers based on the thin foil ferromagnetic metallic glasses are in service, but their size and application are limited due to difficulties in thin foil assembly and manufacturing processes. The new bulk glasses can be cast into exact shapes and substituted into the standard assembly processes now in use for traditional crystalline materials. It is expected that the availability of bulk ferromagnetic glasses will decrease the energy losses of transformers by about 2/3 compared to today's transformers made from crystalline ferromagnetic materials. That's good news for electric utility customers, since it is estimated that power-distribution transformer losses cost about $4 billion annually.

- **Universal Magnetic Behavior in High-Temperature Superconductors.** Understanding high temperature superconductors remains one of the most significant research issues in condensed matter physics. The observed properties of two major classes of high temperature superconductors initially appeared to be significantly different from one other, leading scientists to believe that the fundamental interactions responsible for the superconducting behavior were quite different in the two materials. However, recent neutron scattering results have shown that the superconducting behavior of both major classes of superconductors is connected to excitations of the magnetic spin system in each material. The new results offer insight on high-temperature superconductivity including the promise that a single physical mechanism can account for this phenomenon.

Chemical Sciences Subprogram

- **Measuring Chemical Processes in Combustion One Molecule at a Time.** A powerful new experimental instrument just completed at the Combustion Research Facility promises to provide new information about how molecules dissociate when given enough internal energy. Understanding such processes is critically important for combustion, because, at the high temperatures of combustion, dissociation occurs in a variety of ways that are difficult to observe, model, and predict. In the experiment, pulses of laser light a few femtoseconds in duration pump enough energy into a molecule to cause it to dissociate. (One femtosecond is one millionth of a billionth of a second.) A second femtosecond laser pulse ionizes the molecular fragment during the dissociation process. From the simultaneous measurements of the fragments produced by the second laser, the details of the dissociation process can be extracted. These measurements are made one molecule at a time. This new experimental facility promises to be a tool of unrivaled power for the validation of predictive models and theories of chemical reactions.
- **New Designs for Molecular Wires Help Mimic Photosynthesis.** One way to capture and store the sun's energy is to design systems that mimic photosynthesis. In nature, biological systems use charge separation to store energy. This charge separation occurs by transfer of an electron from a photoexcited donor molecule through a bridge molecule to an acceptor molecule. Researchers have recently constructed donor-bridge-acceptor systems in which the bridge – or molecular wire – is a conjugated organic molecule analogous to natural carotenes that transfer charge over long distances. This research may lead to new molecular devices for efficient charge separation and storage.
- **New Insights into Surface Catalysis.** One of the oldest problems in surface-catalyzed reactions is understanding how the molecules actually come together on a metal surface. Researchers studying the hydrogenation of acetylene on crystalline nickel using sophisticated atomic and molecular beam preparations and subsequent thermal desorption spectroscopy demonstrated that this simple reaction proceeds via hydrogen absorbed into the bulk of the metal rather than adsorbed on its surface, as previously thought. This startling discovery has changed the way we think about industrial hydrogenation catalysts such as Raney nickel and palladium, and may have general implications for heterogeneous catalysts presently used in energy-intensive industries such as ammonia production (the Haber Process).
- **First Observation of Relativistic Thomson Scattering – 60 Years After its Prediction.** British physicist J. J. Thomson, who identified the electron in 1897, showed in 1906 that light could cause electrons to oscillate up and down and reemit at the same frequency in a dipole pattern; this phenomenon was subsequently termed Thomson scattering. Nearly a century later, researchers have demonstrated a new phenomena – relativistic Thomson scattering – in which electrons oscillate in a

more complex figure-8 pattern and emit light at both the exciting laser frequency and multiples of that frequency, each emitted in a different direction. The more complex pattern results from the electron interacting simultaneously with both the electric and magnetic fields of the laser light. To observe this phenomena, the research team built a tabletop neodymium-glass laser and compressed its billionth-of-a-second pulses by a factor of about 1,000, boosting their power to 4 trillion watts of very high-quality beam. This experiment is an important milestone in the study of nonlinear optics with electrons unbound to atoms. Furthermore, this work may lead to new laboratory tabletop x-ray sources producing very short x-ray pulses useful, for example, for probing molecular motion during reactions.

Engineering and Geosciences Subprogram

- **Making Waves**. Unfortunately, many facets of nature exhibit chaotic changes, driven by external forces, never settling down to a predictable state. Progress has been made in understanding one kind of chaos in which information travels from one point to another by means of traveling waves. Examples include the ripples on a wind-blown lake, light in a laser, weather patterns, and even the fibrillation of a human heart. In order to understand this kind of chaos, scientists studied the flow patterns in a thin layer of fluid heated from below. In certain fluid mixtures, the patterns move laterally like waves on a pond. The key discovery is that these patterns can be understood in terms of so-called phase defects, which are places where the waves circle around a point in a pinwheel-like motion. Looking at only the defects to understand the entire pattern is much like keeping track of traffic jams and accidents to understand the operation of a freeway system. The next step will be to predict how the patterns change with time. If present ideas are confirmed, they could be useful controlling such important phenomena as heart fibrillation, and controlling lasers used in communications, cutting and welding.
- **Changes in Seismic Properties of Rocks Detects Damage**. Seismology uses the reflection and transmission of elastic waves to locate subsurface features of interest. Various types of rocks respond differently to different kinds and frequencies of waves. The theoretical geophysics program has developed new techniques to study these phenomena. The research examines rock behavior through ultrasonic resonance experiments, which show that rock has both a rapid resonance response and a slow resonance response. The resonance between the vibrational modes gives the rock a memory of the shaking it has been through. The resonance behavior has implications for accurately locating subsurface features, and for understanding strong ground motion damage patterns during earthquakes when the resonant modes of regions of different ground properties couple with those of man-made structures. A similar resonance response is also characteristic of damaged man-made materials such as metals, ceramics and composites. Thus the nonlinear elastic wave studies can contribute to understanding and testing the characteristics of most man-made materials as well as rock or concrete.

Energy Biosciences Subprogram

- **Orienting Molecular Syntheses.** A component of plant cell walls that severely restricts the use of the carbohydrates in plant biomass is lignin. Lignins are aromatic polymers that make up a significant fraction of the earth's renewable carbon resources. Research has provided evidence that the biosynthesis of these large polymers from smaller lignol units does not proceed in a random fashion, as was previously thought. Novel plant genes have been discovered that encode proteins that serve as a scaffold, helping to hold the lignol units in the right orientation as they are joined together by other biosynthetic enzymes. These results have broad implications for the efficient use of plant biomass as well as offering new strategies for enzyme catalysis in an industrial setting.

- **Plant Cell Walls.** The characteristics of plant cell walls – the major energy component of renewable biological resources – vary to meet the structural, metabolic, and developmental needs of different plant cell types. The biosynthesis of the plant cell wall is precisely regulated to conform to these constraints; however, relatively little is known about how such variation is achieved during cell wall formation. Researchers recently identified an enzyme responsible for modifying the xyloglucan polymer backbone, an important factor in determining cell wall strength. This discovery offers the potential to isolate similar enzymes that modify cell wall properties. A better understanding of plant cell wall biosynthesis can eventually improve the properties of wood and other biomass materials through the efficient design of specific complex carbohydrates and other renewable carbon resources.
- **Designer Enzymes.** Research on fatty acid desaturases and hydroxylases has deciphered the mechanism that controls how these two types of enzymes introduce a double bond (desaturase) or a hydroxyl group (hydroxylase) at specific sites along the carbon atom backbone of long-chain fatty acids. This knowledge of the active site of the two enzymes has enabled the modification of the gene that encodes the desaturase for a specific fatty acid to change it into the hydroxylase and vice versa. Both enzymes perform important tasks in altering the melting response of the fatty acid to heat. This pioneering work lays the groundwork for future advances in designing vegetable oils—which have hundreds of potential uses from heart-healthy margarine to lubricants and nylon.

Scientific Facilities Utilization

The BES program request includes $335,593,000 to maintain support of the scientific user facilities. Included within this request is a cost-of-living increase for operations at each of the four BES synchrotron radiation light sources as well as additional funding to address specific recommendations of the 1997 BESAC review “Synchrotron Radiation Sources and Science” for each of the light sources. Also included within this request are funds to address the critical situation in neutron science following the permanent closure of the High Flux Beam Reactor, e.g., additional operating funds are provided to permit increased operations at other neutron sources and additional capital equipment and accelerator improvement funds are provided for new instruments and infrastructure improvements, respectively. The synchrotron radiation light sources and the neutron sources serve a wide variety of research disciplines, and it is important that these facilities be operated effectively, i.e., that they optimize beam availability and that they reliably serve their users. The funds requested will ensure this high level of operation. Research communities that have benefited from the BES supported Scientific User Facilities include materials sciences, chemical sciences, earth and geosciences, environmental sciences, structural biology, superconductor technology, medical research, and industrial technology development. More detailed descriptions of the specific facilities and their funding are given in the subprogram narratives and in the sections entitled Site Description and Major User Facilities.

Spallation Neutron Source (SNS) Project

The purpose of the SNS Project is to provide a next-generation short-pulse spallation neutron source for neutron scattering. The SNS will be used by researchers from academia, national labs, and industry for basic and applied research and for technology development in the fields of condensed matter physics, materials sciences, magnetic materials, polymers and complex fluids, chemistry, biology, and engineering. It is anticipated that the facility will be used by 1,000-2,000 scientists and engineers annually and that it will meet the Nation's need for neutron science capabilities well into the next century. When completed in 2006, the SNS will be more than ten times as powerful as the best spallation neutron source now in existence -- ISIS at the Rutherford Laboratory in England.

Neutrons enable scientists studying the physical, chemical, and biological properties of materials to determine how atoms and molecules are arranged and how they move. This is the microscopic basis for the features that make materials of technological significance for many economically important areas. Major research facilities, such as the BES synchrotron and neutron sources, are used to understand and "engineer" materials at the atomic level so that they have improved macroscopic properties and perform better in new applications. The SNS is a next-generation facility for just such research. Neutron scattering will play a role in all forms of materials research and design, including the development of smaller and faster electronic devices; lightweight alloys, plastics, and polymers for transportation and other applications; magnetic materials for more efficient motors and for improved magnetic storage capacity; and new drugs for medical care.

The importance of high neutron flux (i.e., high neutron intensity) cannot be overstated. The relatively low flux of existing neutron sources and the very small fraction of neutrons that get scattered by most materials mean most measurements are limited by the source intensity. However, the pursuit of high-flux neutron sources is more than just a desire to perform experiments faster, although that, of course, is an obvious benefit. High flux enables broad classes of experiments that cannot be done with low-flux sources. For example, high flux enables studies of small samples, complex molecules and structures, time-dependent phenomena, and very weak interactions.

The SNS will consist of a linac-ring accelerator system that delivers short (microsecond) pulses to a target/moderator system where neutrons are produced by a process called spallation. The process of neutron production in the SNS consists of the following: negatively charged hydrogen ions are produced in an ion source and are accelerated to 1 giga electron volt (GeV) energy in a linear accelerator (linac); the hydrogen ion beam is injected into an accumulator ring through a stripper foil, which strips the electrons off of the hydrogen ions to produce a proton beam; the proton beam is collected and bunched into short pulses in the accumulator ring; and, finally, the proton beam is injected into a heavy metal target at a frequency of up to 60 Hz. The intense proton bursts striking the target produce pulsed neutron beams by the spallation process. The high-energy neutrons so produced are moderated (i.e., slowed down) to reduce their energies to useful levels, typically by using thermal or cold moderators. The moderated neutron beams are then used for neutron scattering experiments. Specially designed scientific instruments use these pulsed neutron beams for a wide variety of investigations. There will initially be one instrumented target station with the potential for adding more instruments and a second target station later.

The SNS Project partnership among five DOE laboratories takes advantage of specialized technical capabilities within the laboratories: Lawrence Berkeley National Laboratory in ion sources, Los Alamos National Laboratory in linear accelerators, Brookhaven National Laboratory in proton storage rings, Argonne National Laboratory in instruments, and Oak Ridge National Laboratory (ORNL) in targets and moderators.

The Department has been diligent in its efforts to meet the conditions stipulated in the House Report (Report 106-253, pages 113-114) accompanying the FY 2000 Energy and Water Development Appropriations Act concerning the release of construction funds for the SNS project, and has regularly communicated its progress to Congress. During the past year, the project has established a revised project management structure with a single Executive Director who has been designated as the primary authority for the project; filled all senior positions with qualified individuals; established cost and schedule baselines that were externally reviewed and determined to be the most cost effective way to complete the project; and established an inter-Laboratory Memorandum of Agreement and incorporated it by reference into the laboratory contracts, thus making it legally binding.

The FY 2000 budget authority provided for completing most preliminary (Title I) design activities and starting detailed (Title II) design, construction site preparation, long-lead hardware procurement, and continued critical research and development work necessary to reduce technical and schedule risks.

FY 2001 funding of $281,000,000 (includes other project costs) is requested for the SNS Project for conducting detailed (Title II) design and starting fabrication of the ion source, low-energy beam transport, linac structure and magnet systems, target assemblies, experimental instruments, and global control systems. Construction will begin on several conventional facilities in preparation for starting installation of major equipment, and construction will start on the front end building, linac tunnel, high-energy beam transport tunnel, ring-service building, ring-to-beam transport tunnel, and the klystron hall. Construction will be completed on roads into the site, site preparation/grading, waste systems, and retention basins. Production of several significant equipment items such as dipole magnets, material for the target transport systems, and klystrons will continue. Project management and integration activities, which are exceptionally important during this phase of the project, will also be conducted. Work will continue on the Safety Assessment Document for all the facility except for the target system, for which a Safety Analysis Report will be prepared. ORNL has subcontracted to a joint venture by Lester B. Knight and Associates, Inc. and Sverdrup Facilities, Inc. for design and construction of the SNS conventional facilities. Additional information on the SNS Project is provided in the SNS construction project data sheet, project number 99-E-334. The estimated Total Project Cost (TPC) has increased from $1,360,000 to $1,440,000 and the construction schedule has been extended six months to the third quarter of FY 2006 as a result of project restructuring during FY 1999 and the FY 2000 appropriation.

Facility Enhancements

BES will continue to support the following major ongoing enhancements and maintenance activities of existing synchrotron radiation light sources and neutron scattering sources:

(1) Fabrication of instrumentation will continue for the short-pulse spallation source at the Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center (LANSCE). This instrumentation enhancement project was undertaken concurrently with an accelerator enhancement project funded by the Department's Office of Defense Programs. Together, these enhancements will result in a short-pulse spallation source facility equivalent to ISIS in Great Britain, currently the world's best for neutron scattering. This facility meets the requirements set by BESAC for an interim facility to the SNS at least as good as the ISIS facility.

(2) Over the period FY 1999 - FY 2001, a number of improvements are being undertaken at HFIR to improve neutron scattering capabilities. These include larger beam tubes and shutters, a high-performance hydrogen cold source, and neutron scattering instrumentation. The improvements will be undertaken during an extended reactor outage in FY 2000 for the regularly scheduled (approximately every decade) replacement of the beryllium reflector. These improvements require no modification to reactor systems and allow operation at up to 100 MW.

(3) Over the period FY 1999 - FY 2003, the SPEAR 3 upgrade is being undertaken at SSRL to provide major improvements to all existing experimental stations and to significantly benefit the large and growing SSRL user community. The technical goals are to increase injection energy from 2.3 GeV to 3 GeV; decrease beam emittance by a factor of 7; increase operating current from 100 mA to 200 mA; and maintain long beam life time (>25 hr). The increased flux will greatly improve performance in a variety of applications including powder and thin film diffraction, topographic studies, surface microcontamination studies, x-ray tomographic analysis, x-ray absorption studies, and protein crystallography. The magnets and associated vacuum chambers of the existing SPEAR storage ring will be replaced in order to implement the revised lattice system. All components are housed within the existing buildings. The TEC is $58,000,000; DOE and NIH are jointly and equally funding the upgrade. Support from NIH in the amount of $14,000,000 began in FY 1999.

Nanoscale Science, Engineering, and Technology Research

In 1959 Richard Feynman delivered a now famous lecture, *There is Plenty of Room at the Bottom -- An Invitation to Enter a New Field of Physics*. He challenged his audience to envision a time when materials could be manipulated and controlled on the smallest of scales, when new materials could be fabricated and devices could be designed atom by atom. “In the year 2000,” he said, “when they look back at this age, they will wonder why it was not until the year 1960 that anybody began seriously to move in this direction.” [http://www.zyvex.com/nanotech/feynman.html]

Unfortunately, it took longer than Feynman predicted to arrive at the threshold of such complete control of materials. Now, in the year 2000, controlling and manipulating matter at the atomic and molecular scale -- which is the essence of nanoscale science, engineering, and technology -- has finally become feasible. In the 40 years since Feynman’s lecture, instruments have been invented and perfected that enable visualization and control at the nanoscale. Many of these instruments and techniques are contained within the BES collection of scientific user facilities. Theory, modeling, and simulation have also reached the stage at which it is possible to understand and predict phenomena at the nanoscale.

BES has been a leader in the early development of nanoscale science, engineering, and technology since the 1980s, supporting research and sponsoring workshops to help establish the importance of nanostructured materials. Because of the confluence of advances during the past decade, BES is now proposing a major effort in nanoscale science, engineering, and technology to take advantage of opportunities afforded by these advances. This effort has the following broad goals: (1) to attain a fundamental scientific understanding of nanoscale phenomena, particularly collective phenomena; (2) to achieve the ability to design and synthesize materials at the atomic level to produce materials with desired properties and functions; (3) to attain a fundamental understanding of the processes by which living organisms create materials and functional complexes to serve as a guide and a benchmark by which to measure our progress in synthetic design and synthesis; and (4) to develop experimental characterization tools and theory/modeling/simulation tools necessary to drive the nanoscale revolution.

(To better understand what is meant by "nanoscale," ten hydrogen atoms side-by-side span one nanometer, which is one billionth of a meter. A cube one nanometer on a side would contain about one thousand hydrogen atoms. The terms nanoscale science, engineering, and technology generally apply to collections of hundreds to millions of atoms.)

The principal missions of the Department of Energy (DOE) in science, energy, defense, and environment will benefit greatly from developments in these areas. For example, nanoscale synthesis and assembly methods will result in significant improvements in solar energy conversion; more energy-efficient lighting; stronger, lighter materials that will improve efficiency in transportation; greatly improved chemical and biological sensing; use of low-energy chemical pathways to break down toxic substances for environmental remediation and restoration; and better sensors and controls to increase efficiency in manufacturing.

The first goal of this work as noted above is fundamental scientific understanding of structures and interactions at the nanoscale, particularly collective phenomena. It is known that when sample size, grain size, or domain size shrink to the nanoscale, physical properties (such as melting temperature) are strongly affected and may differ dramatically from the corresponding properties in the bulk. Yet, there is remarkably little experience with phenomena at the nanoscale. Because of this limited experience, the physical and chemical properties of nanoscale systems are not understood. In effect, this is a new subject with its own set of physical principles, theoretical descriptions, and experimental techniques. One of the most interesting aspects of materials at the nanoscale involves properties dominated by collective phenomena -- phenomena that emerge from the interactions of the components of the material and whose behavior thus differs significantly from the behavior of those individual components. In some case, collective phenomena can bring about a large response to a small stimulus -- as seen with colossal magnetoresistance, the basis of a new generation of recording memory material. Collective phenomena are also at the core of the mysteries of such materials as the high-temperature superconductors, one of the great outstanding problems in condensed matter physics.

The second goal of this work -- the design and synthesis of materials at the atomic level for desired properties and functions -- is the heart of nanoscale science, engineering, and technology. In the future, design and synthesis of new materials at the atomic level will be accomplished using only the electronic structure of the elements. Furthermore, the properties of new materials will not only be a function of their composition but also of the conditions under which they were synthesized. New synthesis conditions might include nonequilibrium, high pressure, high magnetic field, and high energy density. Also, massively parallel fabrication/characterization combinatorial approaches will be employed. The new field of functional materials would include the design of molecular building blocks, the design of multicomponent structures, and the design of molecular machines.

The third goal of this work is the fundamental understanding of the processes by which living organisms create materials and functional complexes. Nanoscale science, engineering, and technology inexorably links the physical and biological sciences. Nature arranges atoms and molecules precisely into three-dimensional objects of extraordinary complexity to produce objects with required optical, mechanical, electrical, catalytic, and tribological properties. Nature has also learned how to combine materials and structures to build molecular-level machines. Some of these molecular machines serve as pumps, moving material across barriers; others move molecules, structures, or whole cells; others control processes and thus are regulatory systems; and still others produce or convert energy. A major challenge in the physical sciences is to understand how Nature makes these complex objects and molecular machines so that we can develop the tools to design and build materials that function as we want -- materials that have not been envisioned by Mother Nature but use Nature's self assembly techniques.

By understanding and applying these principles to artificial systems, we can make potentially immense advances in diverse areas including energy conversion; data transmission, processing, and storage; "smart" and adaptable materials; sensors for industrial, environmental, and defense purposes; new catalysts; better drugs; and more efficient waste disposal.

The fourth goal of this work is the development of experimental characterization tools and theory/modeling/simulation tools. The history of science has shown that new tools drive scientific revolutions. They allow the discovery of phenomena not previously seen and the study of known phenomena at shorter time scales, at shorter distances, and with greater sensitivity. The BES program has been a leader in the development of tools for characterization at the nanoscale. For example, one of this year's highlights describes the new imaging technique termed Z-contrast imaging, which has resolved adjacent columns of silicon atoms spaced only 0.78 angstroms apart. BES researchers have also been responsible for the development of numerous tools for visualization and characterization at the nanoscale including x-ray microscopes, magnetic flux imaging instrumentation, spectromicroscopy instrumentation including high-brightness infrared spectromicroscopy photoelectron holography, interfacial force microscopes, and atom probe field ion microscopy instrumentation and techniques. Required new instrumentation will necessarily involve an enhancement of conventional techniques -- scanning-probe microscopies, steady-state and time-resolved spectroscopies, and so forth. However, characterization will also depend heavily on revolutionary experimental tools, including techniques for the active control of growth, for massively parallel analysis, and for small sample volumes. Capabilities will be needed for triggering, isolating, or activating single molecules; for independently addressing multiple molecules in parallel; and for transferring or harvesting energy to or from a single molecule. New generations of theory and computational tools will also be required.

This research involves materials sciences, chemistry, physics, biology, and computation. The BES program has worked with the National Science and Technology Council's Interagency Working Group on Nanotechnology, with BESAC, and with the broad scientific community from academia, industry, and the national laboratories to define and articulate the goals of this research and to determine how best to implement a program of research. Based on recent recommendations from BESAC, the BES program will establish a portfolio of programs balanced in scope and in size, ranging from individual principal investigators to large groups. Proposals will be encouraged from relatively small groups of a few principal investigators at universities and/or national laboratories as well as from larger groups focused on particular problems such as might be appropriate for a university center, a national laboratory, or a user facility. Interactions among scientists with a diverse set of skills in areas such as molecular design, synthesis and assembly, molecular modeling, instrumentation development, theory and modeling, and device engineering will also be encouraged. Involvement of young investigators -- graduate students, postdoctoral research associates, and young faculty and staff -- with appropriate expertise is critical to the success of the science and to the evolving future of this field. Interactions among several institutions, including both academic and national laboratory partners, is expected to occur naturally for each of the major focus areas. It is expected that newly funded work will be approximately equally distributed between academic and DOE laboratory efforts.

In the FY 2001 request, new funding in the amount $36,140,000 is requested for these activities. Funds are distributed within the Materials Sciences, Chemical Sciences, and Engineering and Geosciences subprograms. Specific focus areas within each of the subprograms are described in detail in the subprogram narratives. New activities will be peer reviewed following broad solicitations for proposals.

Microbial Cell Research

The recent elucidation of the complete sequences of the genomes of several bacteria offers the opportunity to fundamentally shift our approach to biology. It is now possible to start with the complete parts list and focus on integrating the various parts into a functional whole organism. In the process of integration, it will be possible to understand all of the functions, structures and complex interactions required to permit life in these simplest of life forms. The understanding of the biochemical, metabolic, physiological, and cellular processes will permit the generation of solutions for today's and tomorrow's challenges in energy production and use, environmental cleanup, medicine, agriculture, and industrial processing.

Microbes have dramatic impacts on energy production and conservation. Adverse effects include the fouling or corrosion of pipelines and other metal components used in energy production, significant reductions in the efficiency of heat exchangers, and the souring of fossil energy reserves. Conversely, microbes play a valuable role in numerous industrial fermentations and other bioprocesses that convert complex biomass into potential biofuels and chemical feedstocks.

The developing DNA transfer strategies that build on ongoing work in microbial biochemistry now permit very precise manipulation of genes to elucidate the complex metabolic and gene regulatory circuitry critical for understanding microbes as integrated functional units. The numerous physiological processes of interest, including metabolic changes in response to environmental signals (e.g., starvation, alternative growth substrates, temperature changes, anaerobiosis), the formation of stable consortia, and cellular development, are approachable using molecular techniques and new analytical and imaging instrumentation. The knowledge of the complex interactions that collectively characterize the life and function of these simplest of life forms will permit the control, modification, and use of microbes for both natural and industrial energy-related applications.

New research activities coordinated with activities in the Biological and Environmental Research program focus on a bacterial cell consisting of a minimal set of genes essential for life. The specific research target will be understanding the biochemical and physiological functions of this set of genes. Additional studies will determine the genes and gene functions required for a particular physiological process.

In the FY 2001 request, funding in the amount $2,440,000 is requested for these activities within the Energy Biosciences subprogram. New activities will be peer reviewed following broad solicitations for proposals.

Climate Change Technology Initiative

The FY 2001 budget contains a continuation of two carbon-related programs, each coordinated among several offices and agencies. The first is the Climate Change Technology Initiative (CCTI). CCTI focuses on the underpinning fundamental science that will enable mitigation of climate change. The second is the U.S. Global Change Research Program (US/GCRP). US/GCRP research focuses on developing the fundamental understanding of the comprehensive climate system and the global and regional manifestations of climate change. The two programs complement one another. For example, “A U.S. Carbon Cycle Science Plan” was undertaken by the US/GCRP and the “Carbon Sequestration Research and Development Report” was developed under the auspices of CCTI.

The component of CCTI conducted by the Office of Science focuses on carbon management science and includes sequestration science, science for efficient technologies, and fundamental science to advance low- and no-carbon energy sources. Research begun in the last two years in the area of low/no carbon energy technologies will provide the knowledge base for advanced technologies to reduce carbon dioxide emissions. This work is coordinated between the Basic Energy Sciences (BES) and Biological and Environmental Research (BER) programs, as well as with DOE's technology programs. These activities are expected to impact the Office of Energy Efficiency and Renewable Energy (EE) and the energy and transportation industry by providing options for increased efficiency and reduced energy consumption in manufacturing with improved sensors, controls, and processes. Other aspects of these research projects impact the Office of Fossil Energy (FE) by providing a foundation for effective and safe underground sequestration. The Office of Fossil Energy was a partner with the Office of Science in the development of the "Carbon Sequestration Research and Development Report." As a result, the two offices have a close connection and are jointly funding integrative systems research.

Ongoing CCTI includes two new efforts for carbon sequestration, the sequencing of the DNA of several microbes critical to biological sequestration, and over 50 single investigator and interdisciplinary projects at universities and national laboratories. Research projects span a broad array of disciplines, including ecological, biological, and geological studies of sequestration science; chemical and biological studies of alternative energy sources; new concepts in light-weight energy efficient materials; and more efficient combustion and conversion processes.

Focus areas within the BES program are those that promise the maximum impact in the area of carbon management and that build on strengths of current BES programs. In the Materials Sciences subprogram, research focuses on three areas: high-temperature materials for more efficient combustion, magnetic materials that reduce energy loss during use, and semiconductor materials for solar-energy conversion. In the Chemical Sciences subprogram, a major component of the research aims at reducing emissions of carbon dioxide through fundamental understanding of the chemistries associated with combustion, catalysis, photochemical energy conversion, electrical energy storage, electrochemical interfaces, and molecular specific separation from complex mixtures. In the Engineering and Geosciences subprogram, research emphasizes areas that will impact carbon dioxide sequestration in subsurface geologic formations. The program includes research to understand mechanical stability of porous and fractured reservoirs/aquifers, multiphase fluid flow within the aquifers, and geochemical reactivity in relevant conditions. Finally, in the Energy Biosciences subprogram, research emphasizes the biological process of photosynthesis, which is central to global carbon cycling.

In FY 2001, resources of $19,504,000 are being requested in BES and $16,257,000 in BER for CCTI activities. For BES, the FY 2001 request is the same as the FY 2000 appropriation. These funds will be used to continue the research projects selected in FY 2000. Specific focus areas within each subprogram are described in the subprogram narratives. All CCTI activities are peer-reviewed fundamental scientific research that expand upon core research activities.

Fundamental Research Relating to Solar and Renewable Energy Resources

Included in this request are funds in the amount of $47,100,000 that potentially impact solar and renewable energy resource production and use in the categories of "biomass," "wind energy," "photovoltaics," "hydrogen," and "other (solar photoconversion)." These funds provide continuing support for multidisciplinary, basic research in the BES Materials Sciences, Chemical Sciences, and Energy Biosciences subprograms.

These multidisciplinary research activities are also relevant to a number of other areas that impact energy. Funding totaling $6,300,000 in this category addresses Climate Change Technology Initiative. Indeed, the nature of most of the BES programs is to provide the results of basic research that impact a wide variety of applications. For example, research in the area of biomass focuses on understanding, at the mechanistic level, the biology of plants, algae, and non-medical microbes. While the majority of fundamental research on plants and non-medical microbes is directly related to biomass or renewables, the research also directly impacts many other disciplines and technologies including agricultural food production, plant-derived pharmaceuticals, textile fibers, wood and wood byproducts, environmental restoration, and fermentation technologies. Similarly, research in solar photoconversion focuses on the detailed nature of how molecules in the photo-excited state transfer electrons (and thus energy); this work impacts numerous technologies in addition to solar and renewable energy programs including sensors, molecular photonics, photodegradation of hazardous wastes, photo-assisted synthesis of chemicals, new analytical techniques (or methodologies), soil science, biological electron transfer, and carbon dioxide photoreduction. As a final example, research in photovoltaics focuses primarily on semiconductor physics and the synthesis of semiconductor materials. These materials are also used in microprocessors, batteries, displays, sensors, electrochromic windows, and semiconductor alloys.

Research activities in biomass, wind energy, photovoltaics, hydrogen, and solar photoconversion are coordinated through Coordinating Committees in the Department, through ad hoc meetings, through workshops, and through joint funding at universities and at the Department's laboratories. BES is a participant in the Department's bioenergy initiative, which is an effort to have a fully integrated research and development program focused on biomass and bioenergy products.

Funding of Contractor Security Clearances

In FY 1999, the Department divided the responsibility for obtaining and maintaining security clearances. The Office of Security Affairs, which was responsible for funding all Federal and contractor employee clearances, now pays only for clearances of Federal employees, both at headquarters and the field. Program organizations are now responsible for contractor clearances, using program funds. This change in policy enables program managers to make the decisions as to how many and what level clearances are necessary for effective program execution. In this way, it is hoped that any backlog of essential clearances which are impeding program success can be cleared up by those managers most directly involved. The Office of Science is estimating contractor clearances in FY 2000 and FY 2001 at $313,000 within this decision unit.

Workforce Development

BES-funded research supports U.S. graduate education to ensure the training of future professionals with scientific and engineering skills in areas important to the missions of BES and the Department, i.e., in materials sciences, chemical sciences, geosciences, plant and microbial biosciences, and engineering sciences. BES provides competitive financial support for doctoral degree candidates and post-doctoral investigators as an integral part of the funding for fundamental scientific research in these disciplines. Furthermore, BES scientific user facilities provide outstanding hands-on research experience to many young scientists. Thousands of students and post-doctoral investigators are among the more than 7,000 researchers who conduct experiments at BES-supported facilities each year. The work that these young investigators perform at BES facilities is supported by a wide variety of sponsors including BES, other

Departmental research programs, other federal agencies, and private institutions. This program supported 3,000 graduate students and post doctoral investigators in FY 1999 through grants or contracts; 3,100 graduate students and post doctoral investigators used the BES science user facilities in FY 1999.

Funding Profile

	(dollars in thousands)				
	FY 1999 Current Appropriation	FY 2000 Original Appropriation	FY 2000 Adjustments	FY 2000 Current Appropriation	FY 2001 Request
Basic Energy Sciences					
Research					
Materials Sciences	404,885	405,000	-7,815	397,185	456,111
Chemical Sciences	202,157	209,582	-3,028	206,554	223,229
Engineering and Geosciences	41,665	37,545	-436	37,109	40,816
Energy Biosciences	29,078	31,000	-287	30,713	33,714
Subtotal, Research	677,785	683,127	-11,566	671,561	753,870
Construction	105,400	100,000	0	100,000	261,900
Subtotal, Basic Energy Sciences	783,185	783,127	-11,566	771,561	1,015,770
Use of Prior Year Balances	-4,002 [a]	0	0	0	0
General Reduction	0	-5,066	5,066	0	0
Contractor Travel	0	-3,873	3,873	0	0
Omnibus Rescission	0	-2,627	2,627	0	0
Total, Basic Energy Sciences	779,183 [b]	771,561	0	771,561	1,015,770 [c]

Public Law Authorization:
Public Law 95-91, “Department of Energy Organization Act”
Public Law 103-62, “Government Performance Results Act of 1993”

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total reduction is applied at the appropriation level.

[b] Excludes $15,414,000 which was transferred to the SBIR program and $925,000 which was transferred to the STTR program.

[c] Includes $8,073,000 for Waste Management activities at Ames Laboratory and Argonne National Laboratory that were previously budgeted in FY 1999 and FY 2000 by the Environmental Management program.

Funding by Site

(dollars in thousands)	FY 1999	FY 2000	FY 2001	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	24,950	24,427	27,861	+3,434	+14.1%
National Renewable Energy Laboratory	4,492	5,180	5,116	-64	-1.2%
Sandia National Laboratories	27,142	23,075	23,879	+804	+3.5%
Total, Albuquerque Operations Office	56,584	52,682	56,856	+4,174	+7.9%
Chicago Operations Office					
Ames Laboratory	18,838	16,990	16,165	-825	-4.9%
Argonne National Laboratory – East	144,752	140,005	160,726	+20,721	+14.8%
Brookhaven National Laboratory	79,425	75,441	75,769	+328	+0.4%
Princeton Plasma Physics Laboratory	675	0	0	0	0.0%
Chicago Operations Office	101,483	78,506	80,443	+1,937	+2.5%
Total, Chicago Operations Office	345,173	310,942	333,103	+22,161	+7.1%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	3,709	2,674	3,121	+447	+16.7%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	66,080	63,386	68,537	+5,151	+8.1%
Lawrence Livermore National Laboratory	6,618	6,336	6,195	-141	-2.2%
Stanford Linear Accelerator Facility (SSRL)	26,475	23,042	31,592	+8,550	+37.1%
Oakland Operations Office	37,003	32,286	32,553	+267	+0.8%
Total, Oakland Operations Office	136,176	125,050	138,877	+13,827	+11.1%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science and Education	1,881	745	1,114	+369	+49.5%
Oak Ridge National Laboratory	221,267	207,551	372,644	+165,093	+79.5%
Oak Ridge Operations Office	263	245	228	-17	-6.9%
Total, Oak Ridge Operations Office	223,411	208,541	373,986	+165,445	+79.3%
Richland Operations Office					
Pacific Northwest National Laboratory	12,887	12,063	12,295	+232	+1.9%
Richland Operations Office	163	0	0	0	0.0%
Total, Richland Operations Office	13,050	12,063	12,295	+232	+1.9%
Washington Headquarters	5,082	59,609	97,532	+37,923	+63.6%
Subtotal, Basic Energy Sciences	783,185	771,561	1,015,770	+244,209	+31.6%
Use of Prior Year Balances	-4,002[a]	0	0	0	0.0%
Total, Basic Energy Sciences	779,183[b]	771,561	1,015,770[c]	+244,209	+31.6%

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $15,414,000 which was transferred to the SBIR program and $925,000 which was transferred to the STTR program.

[c] Includes $8,073,000 for Waste Management activities at Ames Laboratory and Argonne National Laboratory that were previously budgeted in FY 1999 and FY 2000 by the Environmental Management program.

Site Description

Ames Laboratory

Ames Laboratory is a Multiprogram Laboratory located on 10 acres in Ames, Iowa The laboratory was built on the campus of Iowa State University during World War II to emphasize the purification and science of rare earth materials. This emphasis continues today. The BES Materials Sciences subprogram supports experimental and theoretical research on rare earth elements in novel mechanical, magnetic, and superconducting materials. Ames scientists are experts on magnets, superconductors, and quasicrystals that incorporate rare earth elements. The BES Chemical Sciences subprogram supports studies of ultrafast spectroscopic techniques to examine energy transfer phenomena, and studies of molecular beams to obtain highly accurate and precise thermochemical information for small molecules and radicals. Ames Laboratory provides leadership in analytical and separations chemistry with strength in catalysis.

The laboratory is also home to the **Materials Preparation Center** (MPC), a user facility dedicated to the preparation, purification, and characterization of rare-earth, alkaline-earth, and refractory metal materials. Established in 1981, the MPC consolidates and makes available to scientists at university, industry, and government facilities the capabilities related to synthesis, processing, and characterization of advanced materials developed at Ames Laboratory during the course of its 40 years of basic research. Although the MPC is designated a national user facility, its operation differs from that of other such facilities in that the users do not conduct experimental or research activities within the Center; rather, they receive high purity materials or unique characterization services that are not available from commercial suppliers, on a full cost recovery basis. The MPC operates the Materials Referral System and Hotline and provides immeasurable value to the superconductivity community by publishing the bi-monthly High Tc Update.

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on 1,700 acres in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. ANL is home to one of the largest BES research efforts, with research activities in broad areas of materials, chemical, and geosciences. It is also the site of three BES supported user facilities -- the Advanced Photon Source (APS), the Intense Pulsed Neutron Source (IPNS), and the Electron Microscopy Center for Materials Research (EMC).

The Materials Sciences subprogram supports research in high-temperature superconductivity; polymeric superconductors; thin-film magnetism; surface science; the synthesis, characterization, and atomistic computer simulation of interfaces in advanced ceramic thin-films; the investigation of the effects of neutron, gamma, and ion-irradiation of solids; tribological investigation of the boundary films on aluminum and aluminum alloys; and synthesis and electronic and structural characterization of oxide ceramic materials, including high-temperature superconductors. The Chemical Sciences subprogram supports research in actinide separations; fundamental physical and chemical properties of actinide compounds; structural aspects fundamental to advanced electrochemical energy storage concepts and the chemistry of complex hydrocarbons; experimental and theoretical studies of metal clusters of catalytically active transition metals; molecular dynamics of gas-phase chemical reactions of small molecules and radicals; photosynthesis mechanisms; and atomic, molecular, and optical physics. ANL has one of three pulsed radiolysis activities that together form a national research program in this area. The other two are at Brookhaven National

Laboratory and Notre Dame University. The Engineering and Geosciences subprogram supports research on processes controlling the mobility of fluids and metals in the Earth's crust.

The **Advanced Photon Source** is one of only three third-generation, hard x-ray, synchrotron radiation light sources worldwide. Dedicated on May 1, 1996, the project was completed five months ahead of schedule and for $13,000,000 less than the baseline construction budget of $811,000,000. The APS has met or exceeded all technical specifications. The design of the 7 GeV synchrotron is optimized for insertion devices. The synchrotron radiation is produced at 34 bending magnets and 34 insertion devices, so that a capacity of 68 independently controlled beamlines can be made available for experimental research. This high-brilliance light source will be used by as many as 2,000 users annually to study the structure and properties of materials in a variety of disciplines including condensed matter physics, materials sciences, chemistry, geosciences, structural biology, medical imaging, and environmental sciences. In addition, the light source will be used for a variety of technological applications, including micromachining and lithography. The first complement of beamlines have been assigned to user groups in Collaborative Access Teams (CATs), whose proposals were reviewed and approved based on their scientific program and the criticality of high-brilliance APS x-rays to their work. The CATs provided approximately $160,000,000 to fund fabrication of the first 40 beamlines at the APS. The facility is now considering proposals for the remaining available beamline ports.

The **Intense Pulsed Neutron Source** is a 30 Hz short-pulsed spallation neutron source using protons from a linac/rapid cycling synchrotron to produce neutrons in a depleted uranium target. Twelve beam lines serve 14 instruments, one of which is a test station for instrument development. IPNS was the first neutron or synchrotron source in the U.S. to operate all instruments in the user mode with time allocated by an external committee. Distinguishing characteristics of IPNS include its innovative instrumentation and source technology and its dedication to serving the users. The first generation of virtually every pulsed source neutron scattering instrument was developed at IPNS. Scientists at IPNS have conceived techniques such as geometric and electronic time focusing, multi-chopper phasing, multiple converging aperture collimation, and neutron reflectometry. In addition, the source and moderator technologies developed at IPNS, including uranium targets, liquid hydrogen and methane moderators, solid methane moderators, and decoupled reflectors, have impacted spallation sources worldwide. Research at IPNS is conducted on the structure of high-temperature superconductors, alloys, composites, polymers, catalysts, liquids and non-crystalline materials, materials for advanced energy technologies, and biological materials. Staff at IPNS are taking a leadership role in the design and construction of instrumentation for the Spallation Neutron Source.

The **Electron Microscopy Center for Materials Research** provides in-situ, high-voltage and intermediate voltage, high-spatial resolution electron microscope capabilities for direct observation of ion-solid interactions during irradiation of samples with high-energy ion beams. The EMC employs a tandem accelerator for simultaneous ion irradiation and electron beam microcharacterization. It is the only instrumentation of its type in the Western Hemisphere. The unique combination of two ion accelerators and two microscopes permits direct, real-time, in-situ observation of the effects of ion and/or electron bombardment of materials and consequently attracts users from around the world.

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is a Multiprogram Laboratory located on 5,200 acres in Upton, New York. BNL is home to BES major research efforts in materials and chemical sciences as well as to efforts in geosciences and biosciences. BNL is also the site of the National Synchrotron Light Source (NSLS).

The Materials Sciences subprogram emphasizes experiments that make use of the NSLS. BNL scientists are among the world leaders in neutron and X-ray scattering applied to a wide variety of research problems such as high-temperature superconductivity, magnetism, structural and phase transformations in solids, and polymeric conductors. BNL has strong research programs in the structure and composition of grain boundaries and interfaces in high temperature superconductors, in aqueous and galvanic corrosion studies, and in the theory of alloy phases.

The Chemical Sciences subprogram supports one of three activities for pulsed radiolysis research at BNL. The innovative short-pulse radiation chemistry facility will contribute significantly to radiation sciences research in the next decade. There is also research on the spectroscopy of reactive combustion intermediates and an active research effort on studies of the mechanisms of electron transfer related to artificial photosynthesis. Other Chemical Sciences research at BNL is focused around the unique capabilities of the NSLS in obtaining time dependant structural data of reacting systems, the structural changes accompanying catalytic and electrochemical reactions, and the formation of atmospheric aerosols and their reactivity.

The Energy Biosciences subprogram supports activities in the plant sciences, which include mechanistic and molecular-based studies on photosynthesis, lipid metabolism, and genetic systems. The studies on lipid biosynthesis may lead to exciting prospects for engineering new pathways for the synthesis of alternative fuels and petroleum-replacing chemicals. The Engineering and Geosciences subprogram supports synchrotron-based studies of rock-fluid interactions, particularly for investigations of diagenetic processes and synchrotron computed microtomography of porosity of reservoir rocks.

The **National Synchrotron Light Source** provides intense focused light from the infrared through the x-ray region of the spectrum by operating two electron storage rings: an X-ray ring and a vacuum ultraviolet (VUV) ring. X-Ray, ultraviolet, visible, and infra-red light from the storage rings is guided into 30 x-ray and 17 VUV beam ports, most of which are split into two to four experimental stations. The NSLS was commissioned in 1982. Annually, 2,300 scientists representing more than 350 institutions, over 50 of them corporations, conduct research at the NSLS in the fields of biology, chemistry, geology, materials science, medicine, metallurgy, and physics. In the basic sciences, researchers investigate the absorption and scattering of light to determine the properties of matter such as crystal structure, bonding energies of molecules, details of chemical and physical phase transformations, electronic structure and magnetic properties. The NSLS also serves as a training ground for future scientists. Between 1988 and 1999, over 600 graduate students used the NSLS in their doctoral thesis research.

The **High Flux Beam Reactor,** commissioned in 1965, is a heavy-water cooled and moderated reactor designed to produce neutrons for scattering. On December 21, 1996, the HFBR was shut down for normal refueling (a routine activity, which occured almost every month). However, before the reactor's scheduled restart, a plume of tritiated water emanating from a leak in the HFBR spent fuel pool was discovered contaminating the groundwater south of the reactor. Since that time, the reactor has been held in standby mode awaiting a decision by the Secretary of Energy on its future. On November 16, 1999, Secretary Richardson announced the permanent closure of the reactor. At that time, activities began that will transition the reactor from standby mode to permanent shut down mode.

Idaho National Engineering and Environmental Laboratory

Idaho National Environmental and Engineering Laboratory (INEEL) is a Multiprogram Laboratory located on 572,000 acres in Idaho Falls, Idaho. The Materials Sciences subprogram supports research in the modeling, growth, and properties of functionally gradient materials as an effective means of joining ceramic and metallic materials, on the microstructural evolution of rapidly solidified materials, and on high strength magnetic materials. The Chemical Sciences subprogram focuses on fundamental understanding of negative ion mass spectrometry, studies of secondary ion mass spectrometry, and computer simulation of ion motion and configuration of electromagnetic fields crucial to the design of ion optics. The Engineering and Geosciences subprogram supports studies to establish controls of biologically based engineering systems, to understand and improve the life expectancy of material systems used in engineering such as welded systems, to improve controls of nonlinear systems, and to develop new diagnostics techniques for engineering systems.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory (LBNL) is a Multiprogram Laboratory located in Berkeley, California, on a 200 acre site adjacent to the Berkeley campus of the University of California. LBNL is home to BES major research efforts in materials and chemical sciences as well as to efforts in geosciences, engineering, and biosciences. LBNL is also the site of two BES supported user facilities -- the Advanced Light Source (ALS) and the National Center for Electron Microscopy (NCEM).

The Materials Sciences subprogram supports research in laser spectroscopy, superconductivity, thin films, femtosecond processes, x-ray optics, biopolymers, polymers and composites, surface science, and theory. Research is carried out on the fundamental features of evolving microstructures in solids; alloy-phase stability; structure and properties of transforming interfaces; the structures of magnetic, optical, and electrical thin films and coatings; processing, mechnical fatigue, and high-temperature corrosion of structure ceramics and ceramic coatings; and the synthesis, structure, and properties of advanced semiconductor and semiconductor-metal systems. The Chemical Sciences subprogram supports fundamental, chemical dynamics research using molecular-beam techniques. Femtosecond spectroscopy studies of energy transfer on surfaces has also been developed. LBNL is recognized for its work in radiochemistry, the chemistry of the actinides, inorganic chemistry, and both homogeneous and heterogeneous chemical catalysis. The Engineering and Geosciences subprogram supports experimental and computational research on rock physics of porous and fractured rock, subsurface imaging through both seismologic and electromagnetic methods, and hydrologic research on fluid flow through both pores and fractures. Geochemical studies focus on advanced interpretations of low-temperature flow processes, innovations in analytical geochemistry, isotope and trace-element chemistry with mass spectrometric and synchrotron-based analyses. Engineering research is concerned with the development of modern nonlinear dynamics with applications to problems in engineering sciences. The Energy Biosciences subprogram focuses on the physics of the photosynthetic apparatus and on the genesis of subcellular organelles.

The **Advanced Light Source**, which began operations in October 1993, is one of the world's brightest sources of ultraviolet light and soft x-rays. Soft x-rays of the ALS are an ideal tool for probing a wide range of electronic structural studies and are particularly useful for x-ray microscopy, surface science, and solid state physics of carbides, actinides and oxides. Such regions of the spectrum also offer special opportunities for research in chemical physics, electron spectroscopy, microscopy, and holography.

The **National Center for Electron Microscopy** provides instrumentation for high-resolution, electron-optical microcharacterization of atomic structure and composition of metals, ceramics, semiconductors, superconductors, and magnetic materials. The facility is home to the Nation's highest voltage microscope, one which specializes in high resolution studies.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on 821 acres in Livermore, California. This laboratory was built in Livermore as a weapons laboratory some distance from the campus of the University of California at Berkeley to take advantage of the expertise of the university in the physical sciences. The Materials Sciences subprogram supports research in metals and alloys, ceramics, materials for lasers, superplasticity in alloys, and intermetallic metals. The Engineering and Geosciences subprogram supports research in the mechanisms and kinetics of low-temperature geochemical processes, laboratory research on the source of electromagnetic response in crustal rocks, modeling and laboratory experiments on rock fracturing, and reactive fluid flow and transport within fractures. The Chemical Sciences subprogram supports plasma assisted catalysis for environmental control of pollutants.

Los Alamos National Laboratory

Los Alamos National Laboratory (LANL) is a Multiprogram Laboratory located on 27,000 acres in Los Alamos, New Mexico. LANL is home to BES major research efforts in materials sciences with other efforts in chemical sciences, geosciences, and engineering. LANL is also the site of the Manuel Lujan Jr. Neutron Scattering Center at the **Los Alamos Neutron Science Center** (LANSCE).

The Materials Sciences subprogram supports research on strongly correlated electronic materials; the theory of evolving microstructures; and plasma immersion processes for ion-beam processing of surfaces for improved hardness, corrosion resistance, and wear resistance. The Chemical Sciences subprogram supports research to understand the electronic structure and reactivity of actinides through the study of organometallic compounds. Also supported is work to understand the chemistry of plutonium and other light actinides in both near-neutral pH conditions and under strongly alkaline conditions relevant to radioactive wastes and research in physical electrochemistry fundamental to energy storage systems. The BES Engineering and Geosciences subprogram supports experimental and theoretical research on rock physics, seismic imaging, and the physics of the Earth's electromagnetic field. Engineering research supports work to study the viscosity of mixtures of particles in liquids.

The **Los Alamos Neutron Science Center** provides an intense pulse source of neutrons for both national security research and civilian research. LANSCE is comprised of a high-power 800-MeV proton linear accelerator (linac), a Proton Storage Ring (PSR), production targets to the Manuel Lujan Jr. Neutron Scattering Center (Lujan Center) and the Weapons Neutron Research (WNR) facility, and a variety of associated experiment areas and spectrometers. Researchers at LANSCE use neutrons to study materials such as polymers, catalysts, and structural composites that are essential for many modern industrial products. The Lujan Center features instruments for measurement of high-pressure and high-temperature samples, strain measurement, liquid studies, and texture measurement. The facility has a long history and extensive experience in handling actinide samples. A new 30 Tesla magnet is available for use with neutron scattering to study samples in high-magnetic fields.

National Renewable Energy Laboratory

National Renewable Energy Laboratory (NREL) is a program-dedicated laboratory (Solar) located on 300 acres in Golden, Colorado. NREL was built to emphasize renewable energy technologies such as photovoltaics and other means of exploiting solar energy. The Materials Sciences subprogram supports basic research efforts that underpin this technological emphasis at the laboratory. For example, theoretical and experimental research on processing and properties of advanced semiconductor alloys and structures provided the basis for the computer-aided design and fabrication of a prototype solar cell; this cell has achieved 30% efficiency in conversion of the solar spectrum into electric energy. The Chemical Sciences subprogram supports research addressing the fundamental understanding of solid-state, artificial photosynthetic systems. This research includes the preparation and study of novel dye-sensitized semiconductor electrodes, characterization of the photophysical and chemical properties of quantum dots, and study of charge carrier dynamics in semiconductors. There is also basic research in catalysis to better understand the chemistry necessary for carbon dioxide conversion.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on 150 acres in Oak Ridge, Tennessee. The BES program provides funding to ORISE for support of a consortium of university and industry scientists to share the ORNL research station at NSLS to study the atomic and molecular structure of matter (known as ORSOAR, the Oak Ridge Synchrotron Organization for Advanced Research). The BES program also funds ORISE to provide support for expert panel reviews of major new proposal competitions, external peer review of DOE laboratory programs, technical review of proposals for DOE's EPSCoR program, and EPSCoR site reviews and the evaluation of program needs and impacts. ORISE also assists in the compilation of annual BES subprogram summary books, the administration of topical scientific workshops, and provides support for other activities such as for the reviews of BES construction projects. ORISE manages the **Shared Research Equipment Program** (SHaRE) at ORNL. The SHaRE Program makes available state-of-the-art electron beam microcharacterization facilities for collaboration with researchers from universities, industry and other government laboratories.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on 24,000 acres in Oak Ridge, Tennessee. ORNL is home to major research efforts in materials and chemical sciences with additional programs in engineering and geosciences. It is the site of the High Flux Isotope Reactor (HFIR) and the Radiochemical Engineering Development Center (REDC). ORNL also leads the five-laboratory collaboration that is designing and constructing the Spallation Neutron Source (SNS).

ORNL has perhaps the most comprehensive materials research program in the country. The Materials Sciences subprogram supports basic research which underpins technological efforts such as those supported by the energy efficiency program. Research is conducted in superconductivity, magnetic materials, neutron scattering and x-ray scattering, electron microscopy, pulsed laser ablation, thin films, lithium battery materials, thermoelectric materials, surfaces, polymers, structural ceramics, alloys; and intermetallics. Research is carried out on the fundamentals of welding and joining and on welding strategies for a new generation of automobiles. The subprogram emphasizes experiments at HFIR and other specialized research facilities that include the High Temperature Materials Laboratory, the Shared Research Equipment (SHaRE) Program, and the Surface Modification and Characterization (SMAC) facility. The SMAC facility is equipped with ion implantation accelerators that can be used to change the physical, electrical, and chemical properties of solids to create unique new materials not possible with conventional processing techniques. Surface modification research has led to important practical applications of materials with improved friction, wear, catalytic, corrosion, and other properties.

The Chemical Sciences subprogram supports research in analytical chemistry, particularly in the area of mass spectrometry, separation chemistry, and thermo-physical properties. Examples of the science include solvation in supercritical fluids, electric field-assisted separations, speciation of actinide elements, ion-imprinted sol-gels for actinide separations, ligand design, stability of macromolecules and ion fragmentation, imaging of organic and biological materials with secondary ion mass spectrometry, and the physics of highly charged species.

The Engineering and Geosciences subprogram investigates experimental and analytical geochemistry with innovative technical approaches for low-temperature geochemical processes in reservoirs and crystal rocks. Engineering research provides support for computational nonlinear sciences such as advanced use of neural nets and sensor fusion, stochastic approximations, and global optimization of cooperating autonomous systems such as cooperating, autolearning robots.

The **High Flux Isotope Reactor** is a light-water cooled and moderated reactor with a design power level of 100 megawatts currently operating at 85 megawatts. HFIR provides state-of-the-art facilities for neutron scattering and materials irradiation and is the world's leading source of elements heavier than plutonium for research, medicine, and industrial applications. HFIR has four horizontal beam tubes, which terminate in the neutron scattering beam room. There are a total of 11 instruments in the beam room and one additional instrument on the upper level. The installation of the new liquid hydrogen cold source will provide beams of cold neutrons for scattering research that are as bright as any in the world. Over the period FY 1999 – FY 2001, a number of improvements will be undertaken at HFIR to improve neutron scattering capabilities. These include the installation of larger beam tubes and shutters, a high-performance hydrogen cold source, and neutron scattering instrumentation. When completed, HFIR will have 14 state-of-the-art neutron scattering instruments on the world's brightest steady-state neutron beams. The improvements will be undertaken during an extended reactor outage in FY 2000 for the regularly scheduled (approximately every decade) replacement of the beryllium reflector.

The **Radiochemical Engineering Development Center**, located adjacent to HFIR, provides unique capabilities for the processing, separation, and purification of transplutonium elements.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The BES Chemical Sciences subprogram supports research in theory and experiments related to the significant environmental clean-up concerns of the Department. Experimental research includes interfacial chemistry of water-oxide systems, near-field optical microscopy of single molecules on surfaces, inorganic molecular clusters, and direct photon and/or electron excitation of surfaces and surface species. Programs in analytical chemistry and in applications of theoretical chemistry to understanding surface catalysis are also supported by the Chemical Sciences subprogram. Included among these studies are high-resolution laser spectroscopy for analysis of trace metals on ultra small samples; understanding of the fundamental inter- and intra-molecular effects unique to solvation in supercritical fluids; and interfacing theoretical chemistry with experimental methods to address complex questions in catalysis. Theoretical, ab-initio quantum molecular calculations are integrated with modeling and experiment. The Materials Sciences subprogram supports research on stress-corrosion cracking of metals and alloys, high-temperature corrosion fatigue of ceramic materials, and irradiation effects in ceramic materials relevant to radioactive waste containment. The Engineering and Geosciences program supports research on basic theoretical and experimental geochemical research that underpins technologies important for the Department's environmental missions and research to improve our understanding of the phase change phenomena in microchannels.

Princeton Plasma Physics Laboratory

Princeton Plasma Physics Laboratory (PPPL) is a program-dedicated laboratory (Fusion Energy Sciences) located on 72 acres in Princeton, New Jersey. The Basic Energy Sciences (BES) program funded a research program that is part of the Department's participation in the AMTEX Partnership™ to enhance the competitiveness of the U.S. Textile Industry. The program, entitled On-Line Process Control (OPCon), seeks to identify and develop technologies to provide faster transition between products, efficient production of small lots, and improved economics via elimination of off-quality production and off-line testing. The BES supported work is focused on development of instrumentation to measure fiber morphology in real time during synthetic fiber production by analysis of passive and active light scattering to measure birefringence of fibers.

Sandia National Laboratories

Sandia National Laboratories (SNL) is a Multiprogram Laboratory located on 3,700 acres in Albuquerque, New Mexico (SNL/NM), with sites in Livermore, California (SNL/CA), and Tonapah, Nevada. SNL is home to significant research efforts in materials and chemical sciences with additional programs in engineering and geosciences. SNL is also the site of the Combustion Research Facility (CRF).

SNL has a historic emphasis on electronic components needed for Defense Programs. The laboratory has very modern facilities in which unusual microcircuits and structures can be fabricated out of various semiconductors. Many of the research projects supported by the Materials Sciences subprogram at SNL/NM are relevant to the overall mission of the laboratory. Included among these are projects on the sol-gel processing and properties of ceramics; the development of nanocrystalline materials through the use of inverse micelles; adhesion and wetting of surfaces of metals, glass, and ceramic materials; theoretical and experimental research of defects; and interfaces in metals and alloys. The leading program on the theory, structure, and dynamics of two-dimensional surface alloys is at SNL/CA.

The BES geophysics research effort at SNL/NM supports fundamental laboratory and imaging studies on rock mechanics, seismologic, and electromagnetic inversion studies, and experimental and theoretical studies on fluid and particulate flow in porous and fractured rock. Geosciences research focuses on theoretical and experimental geochemical investigations of stability and transport within minerals stable in the Earth's crust. Engineering research addresses the viscosity of mixtures of particles in liquids.

The **Combustion Research Facility** at SNL/CA is an internationally recognized facility for the study of combustion science and technology. In-house efforts combine theory, modeling, and experiment including diagnostic development, kinetics, and dynamics. Basic research supported by the Chemical Sciences subprogram is often done in close collaboration with applied problems. Several innovative non-intrusive optical diagnostics such as degenerate four-wave mixing, cavity ring-down spectroscopies, high resolution optical spectroscopy, and ion-imaging techniques have been developed to characterize combustion intermediates. A principal effort in turbulent combustion is coordinated among the BES chemical physics program, the Office of Fossil Energy, and the Office of Energy Efficiency and Renewable Energy.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center (SLAC) is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California. It is the home of the **Stanford Synchrotron Radiation Laboratory** (SSRL) and peer-reviewed research projects associated with SSRL. The Stanford Synchrotron Radiation Laboratory was built in 1974 to take the intense x-ray beams from the SPEAR storage ring that was built for particle physics by the SLAC laboratory. Over the years, the SSRL grew to be one of the main innovators in the production and use of synchrotron radiation with the development of wigglers and undulators that form the basis of all third-generation synchrotron sources. The facility is now comprised of 29 experimental stations and is used each year by over 700 researchers from industry, government laboratories and universities. These include astronomers, biologists, chemical engineers, chemists, electrical engineers, environmental scientists, geologists, materials scientists, and physicists. The Materials Sciences subprogram supports a research program at SSRL with emphasis in both the x-ray and ultraviolet regions of the spectrum. SSRL scientists are experts in photoemission studies of high-temperature superconductors and in x-ray scattering. The SPEAR 3 upgrade at SSRL will provide major improvements to all of the existing operational experimental stations and be of significant and direct benefit to the large and growing SSRL user community.

All Other Sites

The BES program funds research at 149 colleges/universities located in 48 states. Also included are funds for research awaiting distribution pending completion of peer review results.

Materials Sciences

Mission Supporting Goals and Objectives

The Materials Sciences subprogram supports basic research in condensed matter physics, metal and ceramic sciences, and materials chemistry. This basic research seeks to understand the atomistic basis of materials properties and behavior and how to make materials perform better at acceptable cost through new methods of synthesis and processing. Basic research is supported in corrosion, metals, ceramics, alloys, semiconductors, superconductors, polymers, metallic glasses, ceramic matrix composites, catalytic materials, non-destructive evaluation, magnetic materials, surface science, neutron and x-ray scattering, chemical and physical properties, and new instrumentation. Ultimately the research leads to the development of materials that improve the efficiency, economy, environmental acceptability, and safety in energy generation, conversion, transmission, and use. These material studies affect developments in numerous areas, such as the efficiency of electric motors and generators; solar energy conversion; batteries and fuel cells; stronger, lighter materials for vehicles; welding and joining of materials; plastics; and petroleum refining.

Research in nanoscale science will focus on the fundamental properties of nanoscale materials including their structural, physical, and chemical properties; on theory of nanoscale structures bridging atomic and molecular properties with bulk properties; and on the synthesis and processing of new nanoscale materials and materials using nanoscale structures. Research will continue on materials that will mitigate climate change effects of energy production and use by increasing efficiency, reducing energy losses, and displacing fossil fuels; focus areas will continue to be improved heat and corrosion resistant alloys to increase the efficiency of power generation, improved magnetic materials to reduce energy losses in motors, and more efficienct photovoltaic cells to displace fossil fuels.

Performance Measures

- Maintain and operate the scientific user facilities so that the unscheduled down time on average is less than 10 percent of the total scheduled operating time.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Materials Sciences Research	186,621	184,110	210,587	+26,477	+14.4%
Waste Management	0	0	8,073	+8,073	+100.0%
Facilities Operations	218,264	203,596	227,271	+23,675	+11.6%
SBIR/STTR	0[a]	9,479	10,180	+701	+7.4%
Total, Materials Sciences	404,885	397,185	456,111	+58,926	+14.8%

[a] Excludes $9,246,000 which has been transferred to the SBIR program and $555,000 which has been transferred to the STTR program.

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Materials Sciences Research			
■ **Structure of Materials:** This activity supports basic research in the characterization and structure of materials; the relationship of structure to the behavior and performance of materials; predictive theory and modeling; and new materials such as bulk metallic glasses and "nanophase" materials. This activity also provides world-class scientific facilities to the Nation through the operation of four complementary, network-interfaced electron beam microcharacterization user centers at Oak Ridge National Laboratory, Argonne National Laboratory, Lawrence Berkeley National Laboratory, and University of Illinois. These centers contain a variety of highly specialized instruments to characterize localized atomic positions and configurations, chemical gradients, interatomic bonding forces, etc. (FY 2001, $7,428,000) Major activities in FY 2001 will be responsive to the need for advanced instruments with capabilities to characterize and interpret atomic configurations and packing arrangements at the nano-scale with improved resolution and accuracy, including the ability to determine composition, bonding, and physical properties of materials. Needed are: single-atom sensitivity to impurities; 3-dimensional shape determination with atomic accuracy; the ability to find functional sites and determine the origin of the function; and the ability to measure optical absorption and emission from individual elements, preferably with femtosecond time resolution. Many of these advanced tools will come from the further development of current microscopies including scanning tunneling microscopy, confocal and near-field optical microscopy, atomic resolution transmission and scanning transmission electron microscopy, electron energy loss spectroscopy, cathodeluminescence and electron–beam–induced current imaging. However, new instruments are needed as well to image and characterize buried interfaces with nanoscale resolution; these new instruments must operate in a wide range of temperature and environments. Capital equipment is provided for items such as new electron microscopes and improvements to existing instruments.............	24,111	23,841	26,778

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
■ **Mechanical Behavior and Radiation Effects:** These activities support basic research in the mechanical behavior of materials including load-bearing capability, failure and fatigue resistance, fracture toughness and impact resistance, high-temperature strength and dimensional stability, ductility or deformability of materials that is critical to their ease of fabrication, and radiation effects including understanding and modeling of radiation damage and surface modification using ion implantation. These activities relate to energy production and conversion through the need for failure resistant materials that perform reliably in the hostile and demanding environments of energy production and use. The scientific results of this program also contribute to DOE missions in the areas of fossil energy, fusion energy, and radioactive waste storage. Major activities in FY 2001 will include continued development of experimental techniques and methods for the characterization of behavior, the development of a universal model for mechanical behavior that includes all length scales from atomic to bulk dimensions, and advancement of computer simulations for modeling behavior and radiation induced degradation. Capital equipment is provided for items such as in-situ high-temperature furnaces, high-pressure systems, and characterization instrumentation.	16,267	16,570	16,410
■ **Physical Behavior:** This activity supports basic research in the physical behavior of materials, including aqueous, galvanic, and high-temperature gaseous corrosion and their prevention; photovoltaics and photovoltaic junctions and interfaces for solar energy conversion; the relationship to crystal defects and processing parameters to the superconducting current parameters for high-temperature superconductors; phase equilibria and kinetics of reactions in materials in hostile environments such as in the very high temperatures encountered in energy conversion processes; diffusion and the transport of ions in ceramic electrolytes for improved performance batteries and fuel cells. Major efforts in FY 2001 will continue fundamental studies of corrosion resistance and surface degradation, the performance of semiconductors, photovoltaics and high-temperature superconductors and the interactions, and transport of defects in crystalline matter. Capital equipment is provided for items such as spectroscopic instruments, instruments for electronic and magnetic property measurement, and analytical instruments for chemical and electrochemical analysis.	13,496	14,065	13,790

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Engineering Behavior: This activity supports basic research in the engineering behavior of materials. The research includes materials synthesis and processing for new or improved behavior, for minimization of waste, and for hard and wear resistant surfaces; high-rate, superplastic forming of light-weight metallic alloys for fuel efficient vehicles; high-temperature structural ceramics and ceramic matrix composites for high-speed cutting tools and fuel efficient and low-pollutant engines; non-destructive analysis for early warning of impending failure and flaw detection during production; response of magnetic materials to applied static and cyclical stress; plasma, laser, charged particle beam surface modification to increase corrosion resistance; and processing of high-temperature, intermetallic alloys. These activities underpin many of the DOE technology programs, and appropriate linkages have been established in the areas of light-weight, metallic alloys; structural ceramics; high-temperature superconductors; and industrial materials, such as intermetallic alloys. The activity includes the operation of the Materials Preparation Center (FY 2001, $910,000) that makes available small quantities of specialized research quality materials for research purposes that are not commercially or otherwise available.			
Major activities for FY 2001 will include work on thermally unstable systems and large-scale deformation and fracture phenomena. There will be increased research on synthesis and processing of nanoscale materials. This research will include nanoscale films using epitaxial growth; synthesis of nanoparticles; patterned deposition of nanoparticles and clusters; processing of three-dimensional nanoscale structures and composites; and ion implanted nanostructures. The strength of structural elements and modes of failure also will change as the scale of devices and machines decreases toward the nanoscale. The causes of these changes include different mechanical properties that will modify fracture characteristics; the increased importance of surface tension; and, the enhanced role of diffusion and corrosion at the large surface-to-volume ratios that will occur.			
Capital equipment includes furnaces, lasers, processing equipment, plasma and ion sources, and deposition equipment. .	15,226	15,521	18,218

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
■ **Neutron and X-ray Scattering:** This activity supports basic research in condensed matter physics that makes use of neutron and x-ray scattering at major BES-supported user facilities. This research is aimed at a fundamental understanding of the atomic, electronic, and magnetic structure of materials and the effect of structure on the physical properties of materials. In FY 2001, measurements of complex and collective phenomena, particularly in transition metal oxides, using neutron and x-ray scattering will be carried out to achieve greater understanding of how electrons in these materials respond to competing interactions among the charge and spin of electrons and the crystalline lattice. New instruments and techniques to use neutron and x-ray beams will be developed. The level of support for this activity in FY 2001 is determined by balance among all activities in condensed matter physics and by the availability of the neutron and x-ray beams to the scientific community and peer review of proposals. The enhancements of the High Flux Isotope Reactor and the Los Alamos Neutron Science Center, described later, will increase significantly the capacity for neutron scattering. In the long term, the Spallation Neutron Source will make a qualitative difference in the kinds of experiments that can be done. This activity will support increased research in neutron scattering to take advantage of the improved sources and to prepare for the Spallation Neutron Source. Capital equipment is provided for items such as detectors, monochromators, mirrors, and beamline instrumentation.	24,891	23,907	23,441
■ **Experimental Condensed Matter Physics:** This activity supports fundamental experimental research in condensed matter physics. Research includes measurements of the properties of solids, liquids, glasses, surfaces, thin films, artificially structured materials, self-organized structures, and nanoscale structures. This research is aimed at a fundamental understanding of the behavior of materials which underpins all DOE technologies. The materials examined include magnetic materials, superconductors, semiconductors and photovoltaics, liquid metals and alloys, and complex fluids. The measurements include optical and laser spectroscopy, electrical and thermal transport, thermodynamic and phase transition measurements, nuclear magnetic resonance, and scanning-tunneling and atomic-force microscopies. The development of new techniques and			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
instruments including magnetic force microscopy, electron microscopic techniques, and innovative applications of laser spectroscopy is a major component of this activity. Measurements will be made under extreme conditions of temperature, pressure, and magnetic field - especially with the availability of the 100 Tesla pulsed field magnet at LANL.			
Major efforts in FY 2001 will include continued support for investigations of materials with increasingly complex behavior, composition, and structures. A major new activity will be an enhanced emphasis on the growth of extremely high quality crystals of transition metal oxides and subsequent high precision measurements of various physical properties. The development of a sub-Angstrom resolution, Z-constant electron microscope will be continued as will be the development and operation of a 100 Tesla pulsed field magnet at LANL.			
This activity will provide increased support for nanoscale science including research of the optical, electronic, and transport properties of semiconductors at the nanoscale; charge and energy transport at nanometer length scales; magnets with optimum nanoscale configuration; relationship of nanostructures and thermal transport; photonic band gap materials. There will be increased research on ferromagnetism, ferroelectricity, and superconductivity, because these have long been expected to demonstrate substantial changes when structures contain a small number of the relevant particles or when the system size is comparable to the particle size or the coherence length for collective behavior.			
Capital equipment is provided for crystal growth equipment, scanning tunneling microscopes, electron detectors for photoemission experiments, sample chambers, superconducting magnets and computers.	32,420	33,313	35,649

	FY 1999	FY 2000	FY 2001
(dollars in thousands)			
■ **Condensed Matter Theory:** This activity supports basic research in theory, modeling, and simulations. This activity complements much of the experimental work by guiding and stimulating experiments. This activity will provide increased support for theory, modeling and large-scale computer simulation to explore new nanoscale phenomena and the nanoscale regime. The links between the electronic, optical, mechanical, and magnetic properties of nanostructures and their size, shape, topology, and composition are not well understood, although for the simplest semiconductor systems, carbon nanotubes, and similar "elementary" systems there has been considerable progress. However, for more complex materials and hybrid structures even the basic outlines of a theory describing these connections remains to be made. In nanoscale systems, thermal energy fluctuations and quantum fluctuations are comparable to the activation energy scale of the materials and devices, so that statistical and thermodynamic methods must include these effects adequately. Stochastic simulation methods, as well as computational models incorporating quantum and semiclassical methods, are required to evaluate the performance of nanoscale devices. Consequently, computer simulations -- both electronic-structure-based and atomistic -- will play a major role in understanding materials at the nanometer scale and in the development "by design" of new nanoscale materials and devices. The greatest challenge and opportunity will be in those transition regions where nanoscale phenomena are just beginning to emerge from the macroscopic and microscale, regimes which may be described by bulk properties plus the effects of interfaces and lattice defects.			
This activity also supports group efforts in which individual scientists from different backgrounds work together to work on common research areas or make use of a common research facility. Capital equipment is provided for items such as computer work stations, beamline instruments, ion implantation and analytical instruments.	15,124	15,767	18,876
■ **Materials Chemistry:** This activity supports basic research on the chemical properties of materials to understand the effect of chemical reactivity on the behavior of materials and to synthesize new chemical compounds and structures from which better materials can be made. The research is aimed at a			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
fundamental understanding of the behavior of novel materials and structures. This activity includes research in solid state chemistry, surface chemistry, polymer chemistry, crystallography, synthetic chemistry, and colloid chemistry, which underpin technologies such as fuel cells, batteries, membranes, catalysis, electrochemistry, and solar energy conversion. This activity includes investigations of novel materials including low-dimensional, self-assembled monolayers; polymeric conductors; organic superconductors and magnets; complex fluids; and biomolecular materials. The research employs a wide variety of experimental techniques to characterize these materials including x-ray photoemission and other spectroscopies, scanning tunneling and atomic force microscopies, nuclear magnetic resonance (NMR), and x-ray and neutron reflectometry. The activity also supports the development of new experimental techniques such as double rotation NMR, neutron reflectometry, and atomic force microscopy of liquids. Workshops on self-organized materials, and synchrotron x-ray micro-characterization have stimulated increased emphasis for these areas which will begin in FY 2001.			
The systematic and parallel patterning of matter on the nanometer scale also will receive increased support in FY 2001. The controlled positioning of atoms within small molecules is of course routinely achieved by chemical synthesis of identical molecules. Nanometer-size objects are much larger entities, containing thousands or even millions of atoms. There are many powerful new approaches to patterning on the nanoscale that are fundamentally serial in nature, for instance atom manipulation using scanning probe tips or electron beam lithography. The research in this activity will focus on methods to prepare macroscopic quantities of nanoscale components in complex, designed patterns, using techniques of self assembly.			
Capital equipment is provided for such items as chambers to synthesize and grow new materials, nuclear magnetic resonance and electron spin resonance spectrometers, lasers, neutron reflectometers, x-ray beamlines, and atomic force microscopes. ..	25,938	25,796	27,645

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
■ **Experimental Program to Stimulate Competitive Research:** This activity supports basic research spanning the complete range of activities within the Department in states that have historically received relatively less Federal research funding. The EPSCoR states are Alabama, Alaska, Arkansas, Idaho, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, Nevada, North Dakota, Oklahoma, South Carolina, South Dakota, Vermont, West Virginia, and Wyoming, and the Commonwealth of Puerto Rico. Alaska was added to the group of EPSCoR states in FY 2000 and will be eligible for EPSCoR funding in FY 2001. The DOE EPSCoR program supports research cluster activities at six EPSCoR states through cooperative agreements and has awarded individual investigator grants in nearly all EPSCoR states (only Maine and Nebraska are exceptions) and Puerto Rico. The work supported by the EPSCoR program includes research in organic semiconductors, membranes, photochemistry, synchrotron radiation and ion beams, tribology, thin film optoelectronics, catalysis, high energy particle physics, experimental nuclear physics, human genome research, desert vegetation, characterization of petroleum reservoirs, and wind and electrochemical power sources. In FY 2001, an increase is requested to develop scientific manpower in the EPSCoR states through collaborative activities between faculty and students in EPSCoR states and staff in the extensive network of research laboratories and facilities in the Office of Science. Faculty and student teams from EPSCoR states will engage in research programs that couple academic study with hands-on research experiences in national laboratory settings. Workshops and discussions are ongoing with representative scientists from EPSCoR states to acquaint them with the facilities and personnel at the DOE Laboratories...........	6,815	6,815	9,815

EPSCoR Distribution of Funds by State

(dollars in thousands)

	FY 1999	FY 2000 Estimate	FY 2001 Estimate
Alabama	825	75	25
Alaska	0	0	0
Arkansas	100	100	50
Idaho	100	100	50
Kansas	91	95	85
Kentucky	650	200	0
Louisiana	152	146	0
Maine	750	0	0
Mississippi	50	50	50
Montana	75	75	75
Nevada	855	96	0
North Dakota	47	46	0
Oklahoma	100	100	100
Puerto Rico	800	50	0
South Carolina	800	800	750[a]
South Dakota	50	50	0
Vermont	25	25	0
West Virginia	100	100	0
Wyoming	800	800[a]	0[a]
Other	445[b]	3,907[b]	8,630[b]
Totals	6,815	6,815	9,815

[a] In FY 2000, the funding commitment to the State of Wyoming will expire. The State of South Carolina's funding commitment is scheduled to expire in FY 2001.

[b] Includes technical support for the Experimental Program to Stimulate Coompetitive Research (EPSCoR). Uncommitted funds in FY 2000 and FY 2001 will be competed among all EPSCoR states that do not have active Research Implementation Awards to begin new Research Implementation Awards. All EPSCoR states will be eligible for awards for university-laboratory science education partnerships.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
■ **Los Alamos Neutron Science Center (LANSCE) instrumentation enhancement:** This project is a major item of equipment with a total estimated cost of $20,500,000 that will provide enhanced instrumentation at the LANSCE and will be implemented concurrently with an accelerator upgrade funded by the Office of Defense Programs.	4,500	3,500	4,500
■ **Extension of HB-2 Beam Tube at the High Flux Isotope Reactor:** This project, a major item of equipment with a total estimated cost of $5,550,000, which is lower than the original estimate of $5,900,000, will provide beam access for six thermal neutron scattering instruments. Beam guides and optimized geometry will provide a neutron flux at the instrument positions 2-3 times higher than currently available.	2,800	1,600	1,150
■ **Replacement of High Flux Isotope Reactor Monochrometer Drums**	1,800	0	0
■ **Neutron Scattering Instrumentation at the High Flux Isotope Reactor:** Capital equipment funds are provided for new and upgraded instrumentation.	0	0	2,000
■ **SPEAR3 Upgrade:** The SPEAR 3 upgrade at SSRL, which is being funded jointly and equally by DOE and NIH, with initial NIH funding in FY 1999, will provide major improvements to all of the existing operational experimental stations. The increased flux from the bending magnet and wiggler beam lines will greatly extend their performance in a variety of applications including, for example: (1) powder and thin film diffraction studies of materials, (2) topographic studies of materials structure, (3) surface microcontamination on Si wafers, (4) x-ray tomographic analysis, (5) x-ray absorption studies of speciation in environmental samples, and (6) protein crystallography. The magnets and associated vacuum chambers of the existing SPEAR storage ring will be replaced in order to implement the revised lattice system. All components are housed within the existing physical buildings. The DOE portion of SPEAR 3 is a major item of equipment with a total estimated cost of $29,000,000. The total estimated Federal cost, including NIH funding, is about $58,000,000	0	0	8,000

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
■ **Advanced Light Source Beamline:** This beamline is a major item of equipment with a total estimated cost of $6,000,000 that will provide capabilities for surface and interfacial science important to geosciences, environmental science, and aqueous corrosion science. It is being funded jointly by the Materials Sciences Subprogram and the Chemical Sciences Subprogram..	1,500	0	900
■ **Climate Change Technology Initiative:** Basic research focuses on three areas: high temperature materials, magnetic materials, and semiconductor materials. A major goal is the derivation of materials that can withstand higher temperatures for more efficient combustion and for improved properties in applications. Research activities include: (1) an atomic-level understanding of bulk metallic glasses, which have the potential to make significant contributions in corrosion and wear resistance, e.g., in fossil fueled power plants, and on structural ceramics, e.g., for use in high temperature applications such as engine components; (2) surface physics and chemistry of oxide layers, which is expected to produce alloys and coatings that have improved corrosion resistance at high temperatures; (3) the microstructure of magnetic materials, which is expected to result in stronger magnets with reduced energy loss during use; (4) new semiconductor materials, in particular innovative nano and mesoscale physics, which could lead to breakthrough advances in the efficiency of conversion of light to electricity; (5) magnetic materials, which are critical to energy efficiency, since electric motors consume about two-thirds of U.S. electric power; and (6) the development of new semiconductor materials for solar energy conversion stressing very innovative studies in nanoscale and mesoscale physics that might lead to breakthrough advances.	1,733	3,415	3,415
Total, Materials Sciences Research	186,621	184,110	210,587
Waste Management			
■ **Waste Management:** These funds will be provided for disposal of wastes from current activities at ANL and Ames. This activity was funded by Environmental Management prior to FY 2001	0	0	8,073

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Facilities Operations			
■ **Operation of National User Facilities:** The facilities included in Materials Sciences are: National Synchrotron Light Source, Intense Pulsed Neutron Source, Stanford Synchrotron Radiation Laboratory, Manuel Lujan, Jr. Neutron Scattering Center, High Flux Isotope Reactor, Advanced Light Source, and the Advanced Photon Source. Research and development in support of the construction of the Spallation Neutron Source is also included. The facility operations budget request includes operating funds, capital equipment, and Accelerator and Reactor Improvements (AIP) funding under $5,000,000 that are presented in a consolidated manner later in this budget. AIP funding will support additions and modifications to accelerator and reactor facilities that are supported in the Materials Sciences subprogram. Included in the AIP funding are funds for HFIR extended cold guides, extension of the Neutron Sciences Support Building, and general infrastructure upgrades. Capital equipment is needed at the facilities for items such as beam monitors, interlock systems, vacuum systems, beamline front end components, monochromotors, and power supplies. A summary of the funding for the facilities included in the Materials Sciences subprogram is provided below. Additional funds for facility operations for some of these facilities are included in the Chemical Sciences subprogram of this budget....	195,496	184,014	209,750
■ **High Flux Beam Reactor (HFBR):** Funding in FY 2001 is provided to complete the process of placing the Reactor in a safe shutdown condition and for surveillance. Disposition of the scientific instruments is included within this funding. As long as the reactor contains activated components, surveillance activities will continue. Surveillance will continue until the reactor is fully decommissioned and decontaminated.................	22,768	19,582	17,521
Total, Facilities Operations	218,264	203,596	227,271

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
<u>Facilities</u>			
Advanced Light Source	31,206	31,039	35,445
Advanced Photon Source	86,226	85,625	94,677
National Synchrotron Light Source	24,094	24,038	28,293
Stanford Synchrotron Radiation Laboratory	4,046	3,942	4,015
High Flux Beam Reactor	22,768	19,582	17,521
High Flux Isotope Reactor	700	2,400	4,600
Intense Pulsed Neutron Source	12,102	11,699	13,642
Manuel Lujan, Jr. Neutron Scattering Center	7,397	7,371	9,978
Spallation Neutron Source	28,600	17,900	19,100
Partial Offset to Science General Reduction Applied to BES	1,125	0	0
Total, Facilities	218,264	203,596	227,271

SBIR/STTR Funding

■ In FY 1999, $9,246,000 and $555,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.	0	9,479	10,180
Total, Materials Sciences	404,885	397,185	456,111

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Materials Sciences Research	
■ Decrease in research for structure of materials ($-468,000); increase in research in the area of nanoscale science, engineering, and technology for structure of materials ($+3,405,000).	+2,937
■ Decrease in research for mechanical behavior and radiation effects.	-160
■ Decrease in research in physical behavior.	-275
■ Decrease in research for engineering behavior ($-303,000); increase in research in the area of nanoscale science, engineering, and technology for engineering behavior ($+3,000,000).	+2,697

	FY 2001 vs. FY 2000 ($000)
■ Decrease in research for neutron and x-ray scattering.	-466
■ Decrease in research for experimental condensed matter physics ($-654,000); increase in research in the area of nanoscale science, engineering, and technology for experimental condensed matter physics ($+2,990,000).	+2,336
■ Decrease in research for condensed matter theory ($-308,000); increase in research in the area of nanoscale science, engineering, and technology for condensed matter theory, modeling and simulation at the nanoscale ($+3,417,000).	+3,109
■ Decrease in research for materials chemistry ($-503,000); increase in research in the area of nanoscale science, engineering, and technology for experimental condensed matter physics ($+2,352,000).	+1,849
■ Increase in support for the Experimental Program to Stimulate Competitive Research to facilitate student training and university/laboratory science education partnerships.	+3,000
■ Increase in capital equipment for ALS beamline	+900
■ Increase in capital equipment for LANSCE instruments.	+1,000
■ Decrease in capital equipment funds for extension of HB-2 beam tube at HFIR for thermal neutron scattering because of completion of scheduled activities.	-450
■ Increase for SPEAR 3 upgrade	+8,000
■ Increase for the High Flux Isotope Reactor for capital equipment for new and upgraded instrumentation.	+2,000
Total, Materials Sciences Research	+26,477
Waste Management	
■ Increase for Waste Management activities at ANL and Ames	+8,073
Facilities Operations	
■ Increase for the Advanced Light Source for operations, increased support for users, capital equipment, and infrastructure improvements	+4,406
■ Increase for the Advanced Photon Source for operations, increased support for users, capital equipment, fabrication of front ends and insertion devices, and other infrastructure improvements	+9,052
■ Increase for the National Synchrotron Light Source for operations, capital equipment, and infrastructure improvements	+4,255
■ Increase for the Stanford Synchrotron Radiation Laboratory for operations	+73
■ Decrease for the High Flux Beam Reactor operations because of shutdown	-2,061

	FY 2001 vs. FY 2000 ($000)
■ Increase for the High Flux Isotope Reactor for cold guide extensions, an extension of the Neutron Sciences Support Building, and infrastructure improvements.........	+2,200
■ Increase for the Intense Pulsed Neutron Source for operations	+1,943
■ Increase for the Manuel Lujan, Jr. Neutron Scattering Center for the operations....	+2,607
■ Increase in the Spallation Neutron Source research and development funds	+1,200
Total, Facilities Operations.	+23,675
SBIR/STTR	
■ Increase in SBIR/STTR funding because of increase in operating expenses	+701
Total Funding Change, Materials Sciences	+58,926

Chemical Sciences

Mission Supporting Goals and Objectives

The Chemical Sciences subprogram has two major components. One major component is comprised of photo- and radiation chemistry; chemical physics; and atomic, molecular and optical (AMO) science. This research provides a foundation for understanding fundamental interactions of atoms, molecules, and ions with photons and electrons. This work also underpins our fundamental understanding of chemical reactivity. This, in turn, enables the production of more efficient combustion systems with reduced emissions of pollutants. It also increases knowledge of solar photoconversion processes resulting in new, improved systems and production methods. The other major component of the research program is comprised of physical chemistry, inorganic chemistry, organic chemistry, analytical chemistry, separation science, heavy element chemistry, and aspects of chemical engineering sciences. The research supported provides a better molecular level understanding of homogeneous and heterogeneous reactions occurring at surfaces, interfaces, and in bulk media. This has resulted in improvements to known heterogeneous and homogeneous catalytic systems, new catalysts for the production of fuels and chemicals, and better analytical methods in a wide variety of applications in energy processes. It has also provides new knowledge of actinide elements and separations important for environmental remediation and waste management, and better methods for describing turbulent combustion and predicting thermophysical properties of multicomponent systems.

The Climate Change Technology Initiative (CCTI) effort, begun two years ago will continue in FY 2001 at a constant level of effort. New research in nanoscience and computational chemistry will expand the base programs in areas that support the DOE and BES missions. The compelling new science these expanded research efforts promise include understanding the preparation and structure/function relationship of large molecules and molecular assemblies with applications in catalysis, membranes, electochemistry, and chemically reacting flow. Nanoscale systems represent the smallest assemblies of atoms and molecules that demonstrate the collective behavior of macroscopic systems whose properties can be modeled and predicted using modern computational tools based on fundamental quantum theories and which exhibit, in themselves, unique and novel properties as exemplified by buckyballs and nanotubes. The study of chemistry at the nanoscale is crucial for understanding how molecules recognize one another and self-assemble and how chemistry is controlled by and within self-contained nanostructures. Nanoscale chemistry suggests unique control of chemical reactions with a specificity and degree of cooperativity that heretofore has been seen only in the self-replicating chemistry of biological systems. Coupled with computational chemistry, nanoscale research affords an opportunity of unparalleled complexity and imagination. It bridges the gap in chemical understanding between the molecular scale and the laboratory scale of our macroscopic world.

Performance Measures

- Maintain and operate the scientific user facilities so that the unscheduled downtime on average is less than 10 percent of the total scheduled operating time.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Chemical Sciences Research	132,109	131,681	148,893	+17,212	+13.1%
Facilities Operations	69,561	70,173	69,243	-930	-1.3%
SBIR/STTR	0[a]	4,700	5,093	+393	+8.4%
Congressional Direction	487	0	0	0	0.0%
Total, Chemical Sciences	202,157	206,554	223,229	+16,675	+8.1%

Detailed Program Justification

(dollars in thousands)

FY 1999	FY 2000	FY 2001

Chemical Sciences Research

- **Photochemistry and Radiation Research:** The photochemistry and radiation science research program focuses on fundamental molecular level understanding of the capture and conversion of energy. Photochemistry research is centered on understanding capture of energy from light (solar energy) and conversion of that energy into other forms, like electrical or chemical. Among the important chemical issues are the light-induced charge separation needed for chemical reactions to proceed from excited states. Radiation science research focuses on similar processes at the molecular level but associated with the absorption of energy from ionizing radiation. This research provides information on transients in solution and intermediates at liquid/solid interfaces for resolving important issues in solar energy conversion, environmental waste management and remediation; and intermediates relevant to nuclear energy. For FY 2001 the focus will include improved theoretical models of heterogeneous electron transfer; studies of the photophysics and chemistry of excited states; early processes in capture of high energy electrons derived from radiation sources and improved understanding of natural photosynthesis.

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[a] Excludes $4,425,000 which has been transferred to the SBIR program and $265,000 which has been transferred to the STTR program.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
New opportunities offered by nanoscale science, engineering and technology will enable studies of artificial and biological self assembled membranes to isolate and optimally configure chromophores to act as electron-donors and acceptors for efficient charge separation that will allow the desired reaction pathways to be controlled. In addition, studies of quantum dots having unique spectral and electrical properties will be pursued, which have the potential to revolutionize direct solar to electrical energy conversion.			
Capital equipment is provided for such items as lasers, microscope scanners, liquid chromatographs, and temperature controllers.	23,871	23,351	25,842

- **Chemical Physics Research:** This program investigates -- at the molecular level -- chemical reactions in the gas phase, at surfaces, and at interfaces and the relationship between molecular scale phenomena and bulk phenomena. Research activities involve closely-coupled experimental and theoretical efforts. Experimental projects include studies of molecular dynamics, chemical kinetics, spectroscopy, clusters, and surface science. The surface science and clusters research is aimed at providing predictive capability for surface mediated catalysis through provision of explanatory theories relating surface structure to surface mediated chemistry. One of the goals of the chemical physics program is to provide data and techniques for producing or predicting the values of chemical reaction rates to be included in combustion models for predicting the efficiency and emission characteristics of combustion devices and for optimization and control of combustion devices.

  In FY 2001, nanoscience engineering and technology research will expand chemistry of clusters focusing on understanding the relationship between unique electronic properties of nanoscale clusters and their chemical and catalytic properties.

  Another expanded activity in FY 2001 will be theory, modeling, and computational chemistry both at the nanoscale and at the macroscopic scale. Chemistry at the nanoscale is taken to mean the chemistry that occurs between individual molecules, between molecules and small agglomerations or clusters of molecules, and between molecules and surfaces. The behavior of such processes as catalysis, chemical vapor deposition, and combustion is the result of a very large number of individual

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
processes occurring at the nanoscale. Theory and modeling at the nanoscale is concerned with solving the fundamental quantum mechanical equations that describe the chemistry of individual molecules with one another and with extended structures such as clusters and surfaces. Great progress has been made in the past half century in bringing molecular theory and modeling from a purely qualitative aid to an exact predictive tool for three and four atom systems. Moving to the scale of chemistry at the nanoscale, which may involve molecules with tens to hundreds of atoms interacting with themselves and with extended structures, requires new computational tools of greater complexity than are available today. Chemistry at the macroscopic scale involves the processes that relate the microscopic to the macroscopic. Of particular importance is the interaction of chemistry with fluid dynamics. Fluid dynamics is responsible for the mixing of reactants and the removal of products. The energy release in chemical reactions directly affects the fluid dynamics of the reacting system whether it is gas phase, liquid phase, or chemistry at interfaces. Computational chemistry methods based on the tools and theories from statistical mechanics and thermodynamics will be developed and applied with the end of accurate prediction of macroscopic scale chemistry for a range of energy relevant applications. Approximately $2,050,000 is requested for theory, modeling, and simulation of chemistry at the nanoscale; and $1,952,000 is requested for theory, modeling, and simulation of chemistry at the macroscopic scale.			
Capital equipment is provided for such items as pico- and femtosecond lasers, high speed detectors, spectrometers and computational resources.	27,460	26,188	32,784
■ **Atomic, Molecular, and Optical (AMO) Science:** This program supports theory and experiment to understand the interactions among atoms, molecules, ions, electrons, photons, and electromagnetic fields. This work provides the most basic underpinning of a broad spectrum of BES research activities including chemical reactivity, chemical physics, analytical techniques, materials sciences, and new instrumentation. It is this program that contributes knowledge at the most fundamental level necessary for science-based optimization of current energy sources and development of new ones.			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Furthermore, this program has produced our most detailed understanding of the interactions of particles with matter, which enables us to understand the phenomena observed at the BES-supported synchrotron radiation light sources, the electron beam microcharacterization centers, and the neutron scattering facilities. Furthermore, work in AMO science has resulted in new measurement techniques and instrumentation that are widely used by other scientific disciplines and by industry and medical sciences. A continuing series of workshops have helped define areas of priority for BES for FY 2001 and beyond. These areas include studies of novel materials such as nanostructured materials, quantum dots, and artificial atoms; and heavy-ion and highly-charged ion collisions.			
New funding for nanoscience engineering and technology will enable expanded efforts to understand the most fundamental aspects of collective phenomena that are the basis for the unique properties of nanoscale materials.			
Capital equipment is provided for such items as pulse processing electronics, laser upgrades, position sensitive and solid state (SiLi) detectors..	11,018	11,092	12,123
■ **Catalysis and Chemical Transformation:** This activity supports basic research related to chemical transformations and conversions that are fundamental to new or existing concepts for improving energy efficiency, production and storage. The emphasis is on understanding the fundamental chemical principles underlying new and developing technologies. Of particular interest are research activities with the objectives of understanding the chemical aspects of catalysis, both heterogeneous and homogeneous; the chemistry of fossil resources; and the chemistry of precursors to advanced materials. Catalysts are crucial to energy conservation in creating new, less-energy-demanding routes for the production of basic chemical feedstocks and value-added products. The creation of new organometallic precursors has the potential of providing materials that are synthesized by less-energy-intensive processes than older materials they replace or which function as energy-saving media themselves. New opportunities identified for FY 2001 include understanding how the structural changes induced by molecular substrates alter the catalytic activity of surfaces, and understanding chemistry at the interface between water and catalytic oxides.			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
New research enabled by nanoscience engineering and technology will focus on understanding the unique catalytic properties of metal, mixed metal and oxide particles on surface catalyzed reactions, the properties of reactions within nanoscale cavities, and the structure/function and reactivity of nanoscale rafts dispersed on active and inactive supports. Other activities will include the synthesis of discrete nanomaterials derived from molecular building blocks.			
Capital equipment is provided for such items as ultrahigh vacuum equipment, Fourier-transform infrared instrumentation, and high-field, solid-state Nuclear Magnetic Resonance (NMR) spectrometers..	22,304	21,857	24,952

- **Separations and Analyses:** Chemical separations are ubiquitous in Department missions and in industry, and analysis is an essential component of every chemical process, from manufacture through safety and risk assessment. This research addresses the fundamental molecular level questions that underpin chemical separations and analytical methods. The program covers a broad spectrum of separation concepts, including membrane processes, extraction under both standard and supercritical conditions, adsorption, chromatography, photodissociation, and complexation. The effort continues to improve the sensitivity, reliability, and productivity of analytical determinations, as well as enable entirely new approaches to analysis. The program focus is to obtain a thorough understanding of the basic chemistry of separations systems and analytical tools so that their utility can be realized. For FY 2001 new opportunities identified are to more fully understand the responses of molecular systems to changes driven by small energy differences and developing the understanding necessary to enable scaling from the molecular to meso- and finally to macoscale.

  New studies at the nanoscale will address molecular transport in nanoscale structures as well as the formation of macroscopic separation systems via self-assembly of nanoscale precursors. Analytical research will explore monitoring of chemical processes in individual cells along with single-molecule detection in nanoscale volumes.

	FY 1999	FY 2000	FY 2001
Capital equipment is provided for such items as computational workstations and inductively-coupled plasma torch spectrometers for atomic emission determination.	13,463	12,617	14,617
■ **Heavy Element Chemistry:** This program is the principal source of support in fundamental chemistry of the actinide elements for the Nation. The Department has stewardship responsibilities for providing the Nation with basic knowledge of the chemistry of these elements because of their importance to nuclear technology and to the Department's efforts to remediate its former weapons production sites. There are strong links between this activity and the actinide chemistry efforts in the Environmental Management Science Program.			
New opportunities for FY 2001 are in the emerging areas of solid-state speciation and reactivity, and advanced theoretical methods for prediction electronic and molecular structure and reactivity.			
New activities at the nanoscale will focus the role of actinides as probes to understand nanoscale disorder on the chemistry of materials and the chemistry and properties of nanostructures for actinide encapsulation relevant to remediation and drug delivery systems.			
Capital equipment is provided for such items as an x-ray diffractometer and equipment for synchrotron light sources to safely handle the actinides.	6,642	6,720	7,376
■ **Chemical Energy and Chemical Engineering:** This activity addresses energy aspects of chemically related engineering sciences, including thermodynamics, turbulence related to combustion, and physical and chemical rate processes. Particular attention is given to experimental and theoretical aspects of phase equilibria, especially of mixtures, including supercritical phenomena, and to the physics of gas phase turbulence. Also included are fundamental studies of thermophysical and thermochemical properties. Emphasis is given to improving and/or developing the scientific base for engineering generalizations and their unifying theories. Also included is fundamental research in areas critical to understanding the underlying limitations in the performance of non-automotive electrochemical energy storage systems. The			

(dollars in thousands)

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
program covers a broad spectrum of research including fundamental studies of composite electrode structures, failure and degradation of active electrode materials, and thin film electrodes, electrolytes, and interfaces.			
There are strong links with related efforts within the Department and other federal agencies through the Combustion Coordinating Committee and the federal interagency battery consortium.			
For FY 2001 new opportunities highlight the need to couple the current emphasis of the program in molecular simulations with molecular level theory.			
New nanoscience engineering and technology activities will include the controlled chemical modification and construction of nanoscale carbon structures to enable improved molecular electronic devices and electrochemical energy storage and conversion systems.			
Capital equipment is provided for such items as computer work stations and electrochemical apparatus.	9,207	9,009	9,975
■ **Climate Change Technology Initiative:** Basic research in carbon management emphasizes atomic and molecular level understanding of chemical processes to enable predictive capability. Examples of these activities are: understanding charge separation and electron transfer processes critical to photochemical reduction of carbon dioxide with water or hydrogen to hydrocarbons; understanding the interactions and dynamics between molecules and catalysts that result in new catalysts for carbon dioxide insertion into chemicals and understanding the complex relationship between chemical reaction dynamics and turbulence that are critical to improving the efficiency of fossil fuel combustion processes.	2,214	4,394	4,394
■ **General Plant Projects (GPP):** GPP funding is for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems principally at the Ames Laboratory, Argonne National Laboratory, and Oak Ridge National Laboratory as part of the Basic Energy Sciences landlord responsibilities for these laboratories. Funding of this type is essential for maintaining the productivity and usefulness of the Department-owned facilities and in meeting its requirement for safe and reliable facilities operation. Additional			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
GPP funding is included in the Facilities Operations justification. The total estimated cost of each GPP project will not exceed $5,000,000	10,844	10,153	10,275
■ **General Purpose Equipment (GPE):** GPE funding is provided for Ames Laboratory, Argonne National Laboratory, and Oak Ridge National Laboratory as part of the Basic Energy Sciences responsibilities for these laboratories for general purpose equipment that supports multipurpose research.	5,086	5,550	5,655
■ **Advanced Light Source Beamline:** This beamline is a major item of equipment with a total estimated cost of $6,000,000 that will provide capabilities for surface and interfacial science important to geosciences, environmental science, and aqueous corrosion science. It is being funded jointly by the Materials Sciences Subprogram and the Chemical Sciences Subprogram	0	750	900
Total, Chemical Sciences Research	132,109	131,681	148,893

Facilities Operations

	FY 1999	FY 2000	FY 2001
■ **Facilities Operations:** The facilities included in Chemical Sciences are: National Synchrotron Light Source, High Flux Isotope Reactor, Radiochemical Engineering Development Center, Stanford Synchrotron Radiation Laboratory, and Combustion Research Facility. The facility operations budget request, which includes operating funds, capital equipment, general plant projects, and AIP funding under $5,000,000, is described in a consolidated manner later in this budget. A summary table of the facilities included in this Chemical Sciences subprogram is provided below. Additional funds for facility operations for some of these facilities are included in the Materials Sciences subprogram of this budget. AIP funding will support additions and modifications to accelerator and reactor facilities, which are supported in the Chemical Sciences subprogram. General Plant Project (GPP) funding is also required for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems. The total estimated cost of each GPP project will not exceed $5,000,000. Capital equipment is needed for the facilities for items such as beam monitors, interlock systems, vacuum systems, beamline front end components, monochromators, and power supplies	69,561	70,173	69,243

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Facilities			
National Synchrotron Light Source	8,082	8,071	8,207
Stanford Synchrotron Radiation Laboratory	19,373	17,982	18,459
High Flux Isotope Reactor	29,659	32,132	29,601
Radiochemical Engineering Development Center	7,027	6,985	7,145
Combustion Research Facility	5,024	5,003	5,831
Partial Offset to Science General Reduction Applied to BES	396	0	0
Total, Facilities	69,561	70,173	69,243

SBIR/STTR Funding

■ In FY 1999, \$4,425,000 and \$265,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.	0	4,700	5,093

Congressional Direction

■ Funds research related to identification of trace element isotopes in environmental samples at the University of Nevada – Las Vegas (per Congressional Direction)	487	0	0
Total, Chemical Sciences	202,157	206,554	223,229

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Chemical Sciences Research	
■ Increase in research for photochemistry and radiation research ($+591,000); and increase in research in the area of nanoscale science engineering, and technology for photochemistry and radiation research ($+1,900,000).	+2,491
■ Increase in research for chemical physics ($+664,000); increase in research in the area of nanoscale science engineering, and technology for chemical physics ($+3,980,000); and increase in research for theory, modeling, and simulation in nanoscale chemistry and in computational chemistry ($+1,952,000).	+6,596
■ Increase in research for atomic, molecular and optical sciences ($+281,000); and increase in research in the area of nanoscale science engineering, and technology for atomic, molecular and optical sciences ($+750,000).	+1,031
■ Increase in research for catalysis and chemical transformation ($+555,000); and increase in research in the area of nanoscale science engineering, and technology for catalysis and chemical transformations ($+2,540,000).	+3,095
■ Increase in research for separations and analysis ($+320,000); and increase in research in the area of nanoscale science engineering, and technology for separations and analysis ($+1,680,000).	+2,000
■ Increase in research for heavy element chemistry ($+170,000); and increase in the area of nanoscale science engineering, and technology for heavy element chemistry ($+486,000).	+656
■ Increase in research for chemical energy and chemical engineering ($+231,000); and increase in research in the area of nanoscale science engineering, and technology for chemical energy and chemical engineering ($+735,000).	+966
■ Increase in research for ALS Beamline	+150
■ Increase in GPE.	+105
■ Increase in GPP.	+122
Total, Chemical Sciences Research	+17,212
Facilities Operations	
■ Increase for the National Synchrotron Light Source for operations	+136
■ Increase for the Stanford Synchrotron Radiation Laboratory for operations	+477

	FY 2001 vs. FY 2000 ($000)
■ Increase for the High Flux Isotope Reactor for operations and to provide increased support for users	+3,448
■ Decrease funding for the High Flux Isotope Reactor in accordance with completion of the Be reflector	-5,979
■ Increase for Radiochemical Engineering Development Center	+160
■ Increase for the Combustion Research Facility for operations	+828
Total, Chemical Sciences Facilities	-930
SBIR/STTR	
■ Increase SBIR/STTR funding because of increase in operating expenses	+393
Total Funding Change, Chemical Sciences	+16,675

Engineering and Geosciences

Mission Supporting Goals and Objectives

The Engineering and Geosciences subprogram conducts research in two disciplinary areas, engineering and geosciences. In Engineering Research, the goals are to extend the body of knowledge underlying current engineering practice to create new options for improving energy efficiency and to broaden the technical and conceptual knowledge base for solving the engineering problems of energy technologies. In Geosciences Research, the goal is on fundamental knowledge of the processes that transport, concentrate, emplace, and modify the energy and mineral resources and the byproducts of energy production. The research supports existing energy technologies and strengthens the foundation for the development of future energy technologies. Ultimately the research impacts control of industrial processes to improve efficiency and reduce pollution, to increase energy supplies, and to lower cost and increase the effectiveness of environmental remediation of polluted sites.

Engineering Research will have increased emphasis on fundamental engineering principles that are needed to exploit advances in nanoscale science, including thermal and mechanical properties at the nanoscale; control methods for nanosystems; reliable packaging, assembling, powering, and actuating of nano-devices; and instrumentation for on-line diagnostics and control of nanodevices. In addition, a new, university-based research effort in Robotics and Intelligent Machines will focus on sensors and sensor integration, remote operation and data acquisition, and controls. Geosciences Research will continue activities in Climate Change Technology research to gain the scientific understanding for improving the characterization of subsurface formations and their host potential for carbon dioxide sequestration.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Engineering Research	17,476	14,352	17,767	+3,415	+23.8%
Geosciences Research	24,189	21,819	22,027	+208	+1.0%
SBIR/STTR	0[a]	938	1,022	+84	+9.0%
Total, Engineering and Geosciences	41,665	37,109	40,816	+3,707	+10.0%

[a] Excludes $1,013,000 which has been transferred to the SBIR program and $61,000 which has been transferred to the STTR program.

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Engineering Research			
■ **Engineering Research:** The Engineering Research activity supports work in mechanical systems including fluid mechanics, heat transfer, and solid mechanics; systems sciences including process control, instrumentation, and intelligent machines and systems; and engineering analysis including nonlinear dynamics, data bases for thermophysical properties, models of combustion processes for engineering applications and foundation of bioprocessing of fuels, and energy related waste and materials. In FY 2001, a program will be established in nanoscale science, engineering, and technology with emphasis on fundamental engineering principles that are needed to exploit advances in nanoscale science, including thermal and mechanical properties at the nanoscale; control methods for nanosystems; reliable packaging, assembling, powering, and actuating of nano-devices; and instrumentation for on-line diagnostics and control of nanodevices. In addition, in FY 2001, a new, university-based research effort in Robotics and Intelligent Machines will focus on sensors and sensor integration, remote operation and data acquisition, and controls. ($1,947,000).	17,476	14,352	17,767
Geosciences Research			
■ **Geosciences Research:** The Geosciences subprogram supports basic research in geochemistry and geophysics. The objective is to advance our understanding of fundamental geological processes so we can make wise choices among current and emerging energy and environmental technologies. Geochemical research focuses on fundamental understanding of subsurface solution chemistry, mineral-fluid interactions, mineral thermodynamics and natural isotopic systems. These studies provide a critical foundation for understanding oil, gas, and geothermal resource recovery and control of contaminants in groundwater flow. Geophysical research focuses on understanding the physical properties of fluids, rocks and minerals and developing improved methods to image these properties. Geophysical imaging is the key for non-invasive discovery and monitoring subsurface reservoirs, fluid pathways,			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
and physical property distributions in the earth. These studies provide the fundamental science base for new capabilities to locate and monitor oil and gas reservoirs, contaminant migration and for characterizing disposal sites for energy related wastes. Improved understanding of earth processes is required to quantitatively predict the response of earth systems to natural and man-made perturbations	22,792	14,997	15,205
■ **Climate Change Technology Initiative:** Geosciences research will continue to emphasize improved understanding of fundamental geological processes that impact concepts for sequestration of carbon dioxide in subsurface reservoirs. The research will continue with its focus on four areas: (1) improved understanding of the mechanical stability of porous and fractured reservoirs/aquifers over injection periods required for sequestration; (2) improved understanding of multiphase fluid flow within aquifers; (3) improved understanding of the geochemical reactivity within and among fluids, and between fluids and rock material within reservoirs/aquifers; (4) improving the resolution of geophysical imaging to monitor the injection and storage integrity during the lifetime of the sequestration site..	1,397	6,822	6,822
Total, Geosciences Research...	24,189	21,819	22,027
SBIR/STTR Funding			
■ In FY 1999, $1,013,000 and $61,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.	0	938	1,022
Total, Engineering and Geosciences	41,665	37,109	40,816

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Engineering Research	
■ Decrease in core engineering research ($-293,000); and increase in research in the area of nanoscale science, engineering, and technology ($+1,761,000).	+1,468
■ Increase for new, university-based research effort in Robotics and Intelligent Machines.	+1,947
Total, Engineering Research	+3,415
Geosciences Research	
■ Increase in research	+208
SBIR/STTR Funding	
■ Increase SBIR/STTR funding because of increase in operating expenses	+84
Total Funding Change, Engineering and Geosciences	+3,707

Energy Biosciences

Mission Supporting Goals and Objectives

The Energy Biosciences subprogram supports fundamental research related to a molecular level understanding of the formation, storage, and interconversion of energy by plants and microorganisms. Plants and microbes serve as renewable resources for fuel and other fossil resource substitutes, as agents to restore previously disrupted environmental sites, and as potential components of industrial processes to produce new products and chemicals in an environmentally benign manner. The program supports research in a number of topics related to these areas. These include research in photosynthesis and bioenergetics; the biosynthesis, structure and function of plant cell walls (the major component of plant biomass); the bioproduction and bioconversion of methane; the biodegradation of lignocellulose; the biosynthesis of starch and lipids (plant energy storage compounds); plant secondary metabolism; microbial fermentations; microbial thermophily; and processes that offer unique possibilities for research at the interface of biology and the physical, earth, and engineering sciences.

Research will continue on activities that impact climate change, including investigations of plants, algae, and microbes and their role in the capture and release of atmospheric carbon dioxide. The biological processes of carbon dioxide fixation offer numerous possibilities leading to the reduction of atmospheric carbon dioxide levels by replacing fossil-derived fuels with renewable resources or providing fixed carbon for long-term sequestration. New research in microbial cell will focus on understanding the complete physiological and biochemical roles of the genes required for growth and specific bioprocesses. This information will enable the control, modification, and use of microbes for both natural and industrial energy-related applications.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Energy Biosciences	29,078	29,914	32,839	+2,925	+9.8%
SBIR/STTR	0[a]	799	875	+76	+9.5%
Total, Energy Biosciences	29,078	30,713	33,714	+3,001	+9.8%

[a] Excludes $730,000 which has been transferred to the SBIR program and $44,000 which has been transferred to the STTR program.

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Energy Biosciences Research			
■ **Photosynthesis:** Photosynthesis is the capture of solar energy by plants and photosynthetic microbes. A broad range of research activities is supported to understand the detailed mechanisms of this fundamental process. The approaches used to dissect the photosynthetic machinery range from biophysical studies to traditional biochemical and molecular genetic analyses. The work interfaces with the photochemistry activities supported in the Chemical Sciences subprogram to provide a complete analysis from the physical to the biological level. A prominent area of interest is the examination of the mechanisms used to transfer energy from numerous accessory pigments into the reactive center where oxygen evolution and energy transduction occur. The approach of using molecular genetics to modify a single amino acid (the fundamental component of proteins) followed by biophysical analysis of the effects on energy transfer is providing a detailed picture of the function of the various proteins and cofactors involved in this processes. A number of studies provide indications that evolution has attempted to optimize the photosynthesis process to assure that the organisms have sufficient energy to survive in as many environmental situations as possible, particularly under conditions of very low light. It is likely that, through fundamental understanding, it may be able to modify this process to have much higher efficiencies under high light conditions.	4,315	4,055	4,039

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
■ **Biological Synthesis:** Plants and microorganisms are important commercial sources of materials such as cellulose (paper and wood), starch, sugars, oils, waxes, and many biopolymers. These renewable, energy-rich biomaterials can also comprise a biomass resource for energy production and conservation. When all plants and microorganism are considered, their collective genetic capacity to synthesize different energy-rich organic compounds and polymers is almost limitless. Genomics, including research on genetic mechanisms controlling growth, metabolism, and cellular functions in plants and microbes, is already yielding biotechnological tools and promising opportunities to specify the type of starch and oil produced, and has even been used to move microbial genes into plants for the synthesis of thermal plastics. Plant and microbial genomics is experiencing tremendous expansion. An example is the large scale sequence of the entire Arabidopsis genome a project jointly funded with the NSF and USDA, which is expected to be completed at the close of the year 2000. Arabidopsis is a model for all plants and knowledge of its genome is being used to locate and study genetic traits in other plants ranging from corn to poplar trees. The great challenge and exciting opportunity ahead is to place this genomic complement within a functional context. For the first time, enormous possibilities are developing for defining entire gene expression profiles in response to developmental, environmental, or metabolic requirements. The functional genomics of energy-related processes in plants is a critical component of the interagency National Plant Genome research. The comprehensive ramifications for efficient energy utilization and renewal are particularly great as genomic information is integrated with existing biochemical and biophysical information in living systems.	15,089	14,185	14,712
■ **Metabolic Interconversion:** Research in this area includes the conversion of minerals or simple organic molecules to biologically useful energy-rich compounds; the degradation and recycling of biomass in the form of plant lignins or celluloses by fungi or bacteria; the syntrophic or symbiotic relationship between different plant and microbial species to facilitate the utilization and interconversion of biological macromolecules; the microbial production of biofuels such as hydrogen or methane through respiration and fermentation; the development			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
of strategies to convert toxic substances into benign or beneficial biological molecules; and the use of natural biological processes and molecules to synthesize new classes of biological materials.	7,239	6,801	6,775
■ **Microbial Cell Research:** The strengths of the Energy Biosciences subprogram in microbial biochemistry and physiology will be combined with the strengths of the Biological and Environmental Research program in genomics, structural biology and computational biology in a coordinated program to establish a minimal set of genes required for bacterial growth. The Energy Biosciences subprogram will be involved in the biochemical and physiological characterization of the minimal gene set along with describing the genes (gene modules) and gene functions associated with specific physiological and biochemical processes of interest to the Department of Energy. Examples of these bioprocesses include extracellular polymer degradation, photoautotrophy, cell movement, syntrophic or synergistic interactions with other bacterial, and responses to external physical stresses. Of particular scientific interest is understanding how these individual gene modules and their encoded bioprocesses interact at the molecular level to permit control and stability in the entire microbial cell. Along with enabling the creation of specific microbes with specific physiological properties, this research will lead to a more complete understanding of the microbial cell, its genes, proteins and regulatory systems that define microbial life with its distinct physiological and biochemical characteristics.	0	0	2,440
■ **Climate Change Technology Initiative:** Basic research begun in FY 1999 emphasizes the biological process of photosynthesis, which is central to global carbon cycling. The focus is on studies on the mechanism of photosynthetic carbon fixation and the subsequent metabolism of the fixed carbon. Specific attention is being directed at steps in carbon fixation that regulate or limit the entire process. Another focus area of is the synthesis and biodegradation of particularly recalcitrant forms of fixed carbon. The understanding obtained from these			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
and related studies will permit the production of radical changes in photosynthetic carbon capture by manipulating both the efficacy of the photosynthetic apparatus and its function in whole plants and other photosynthetic organisms	2,435	4,873	4,873
Total, Energy Biosciences Research	29,078	29,914	32,839
SBIR/STTR Funding			
■ In FY 1999, $730,000 and $44,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.	0	799	875
Total, Energy Biosciences	29,078	30,713	33,714

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Energy Biosciences Research	
■ Decrease in research in photosynthesis	-16
■ Decrease in research in biological synthesis	-57
■ Increase for the National Plant Genome research	+584
■ Decrease in research in metabolic interconversion	-26
■ Increase in research in microbial cells	+2,440
Total, Energy Biosciences Research	+2,925
SBIR/STTR	
■ Increase in SBIR/STTR funding because of increase in operating expenses.	+76
Total Funding Change, Energy Biosciences	+3,001

Construction

Mission Supporting Goals and Objectives

Construction is needed to support the research in each of the subprograms in the Basic Energy Sciences program. Experiments necessary in support of basic research require that state-of-the-art facilities be built or existing facilities modified to meet unique research requirements. Reactors, radiation sources, and neutron sources are among the expensive, but necessary, facilities required. The budget for the BES program includes funding for the construction and modification of these facilities.

Performance Measures

- Meet the cost and schedule milestones for upgrade and construction of scientific user facilities, including the construction of the Spallation Neutron Source. The cost and schedule will be kept within 10 percent of cost and schedule baselines as reflected by regular external independent reviews of project management cost and schedule.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Construction	105,400	100,000	261,900	+161,900	+161.9%
Total, Construction	105,400	100,000	261,900	+161,900	+161.9%

Detailed Program Justification

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
Construction			
■ Funding for the Combustion Research Facility, Phase II was completed in FY 1999 as scheduled	4,000	0	0
■ The FY 2001 requested budget authority for the Spallation Neutron Source will provide for: detailed (Title II) design and starting fabrication of the ion source, low-energy beam transport, linac structure and magnet systems, target assemblies, experimental instruments, and global control systems; completing detailed design and starting construction of major conventional facilities; continued procurements of major			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
technical components (e.g., dipole magnets and klystrons); and continued preparation of a Safety Analysis Report for the target system and a Safety Assessment Document for the remainder of the Spallation Neutron Source facility.	101,400	100,000	261,900
Total, Construction	105,400	100,000	261,900

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Construction	
■ The increase in funding for the Spallation Neutron Source represents the scheduled ramp up of activities.	+161,900
Total Funding Change, Construction	+161,900

Major User Facilities

Mission Supporting Goals and Objectives

The BES scientific user facilities provide experimental capabilities that are beyond the scope of those found in laboratories of individual investigators. Synchrotron radiation light sources, high-flux neutron sources, electron beam microcharacterization centers, and other specialized facilities enable scientists to carry out experiments that could not be done elsewhere. These facilities are part of the Department's system of scientific user facilities, the largest of its kind in the world. A description of each facility is provided in the "Site Descriptions" section. Any unusual or nonrecurring aspects of funding are described in the following section "Detailed Program Justification."

The facilities are planned in collaboration with the scientific community and are constructed and operated by BES for support of forefront research in areas important to BES activities and also in areas that extend beyond the scope of BES activities such as structural biology, medical imaging, and micro machining. These facilities are used by researchers in materials sciences, chemical sciences, earth and geosciences, environmental sciences, structural biology, superconductor technology, and medical research and technology development. The facilities are open to all qualified scientists from academia, industry, and the federal laboratory system whose intention is to publish in the open literature. The funding schedule includes only those facilities that have operating budgets for personnel, utilities, and maintenance.

Funding Schedule

Funding for the operation of these facilities is provided in the Materials Sciences and Chemical Sciences subprograms.

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Advanced Light Source	31,206	31,039	35,445	+4,406	+14.2%
Advanced Photon Source	86,226	85,625	94,677	+9,052	+10.6%
National Synchrotron Light Source	32,176	32,109	36,500	+4,391	+13.7%
Stanford Synchrotron Radiation Laboratory	23,419	21,924	22,474	+550	+2.5%
High Flux Beam Reactor	22,768	19,582	17,521	-2,061	-10.5%
High Flux Isotope Reactor	30,359	34,532	34,201	-331	-1.0%
Radiochemical Engineering Development Center	7,027	6,985	7,145	+160	+2.3%
Intense Pulsed Neutron Source	12,102	11,699	13,642	+1,943	+16.6%
Manuel Lujan, Jr. Neutron Scattering Center	7,397	7,371	9,978	+2,607	+35.4%
Spallation Neutron Source	28,600	17,900	19,100	+1,200	+6.7%
Combustion Research Facility	5,024	5,003	5,831	+828	+16.6%
Partial Offset to Science General Reduction Applied to BES	1,521	0	0	0	-
Total, Major User Facilities	287,825	273,769	296,514	+22,745	+8.3%

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Facilities Operations			
■ Advanced Light Source at Lawrence Berkeley National Laboratory.	31,206	31,039	35,445
■ Advanced Photon Source at Argonne National Laboratory.	86,226	85,625	94,677
■ National Synchrotron Light Source at Brookhaven National Laboratory.	32,176	32,109	36,500
■ Stanford Synchrotron Radiation Laboratory at Stanford Linear Accelerator Center.	23,419	21,924	22,474
■ High Flux Beam Reactor at Brookhaven National Laboratory. The reactor has been in standby mode since December 21, 1996, awaiting a decision by the Secretary of Energy on its future. On November 16, 1999, Secretary Richardson announced the permanent closure of the reactor. The funding requested in FY 2001 represents that required to continue the transition project that will complete the shut down and provide for appropriate disposition of the scientific instruments and ancillary equipment. Surveillance will continue until the reactor is fully decommissioned and decontaminated.	22,768	19,582	17,521
■ High Flux Isotope Reactor at Oak Ridge National Laboratory.	30,359	34,532	34,201
■ Radiochemical Engineering Development Center (REDC) at Oak Ridge National Laboratory.	7,027	6,985	7,145
■ Intense Pulsed Neutron Source at Argonne National Laboratory.	12,102	11,699	13,642
■ Manuel Lujan, Jr. Neutron Scattering Center at Los Alamos National Laboratory.	7,397	7,371	9,978
■ Spallation Neutron Source at Oak Ridge National Laboratory.	28,600	17,900	19,100
■ Combustion Research Facility at Sandia National Laboratories/California.	5,024	5,003	5,831
■ Partial Offset to Science General Reduction Applied to BES.	1,521	0	0
Total, Major User Facilities	287,825	273,769	296,514

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
General Plant Projects	11,194	10,500	10,625	+125	+1.2%
Accelerator Improvement Projects	8,927	8,918	13,195	+4,277	+48.0%
Capital Equipment	56,236	51,517	71,146	+19,629	+38.1%
Total, Capital Operating Expenses	76,357	70,935	94,966	+24,031	+33.9%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1999	FY 2000	FY 2001	Unapprop-riated Balances
99-E-334 Spallation Neutron Source, ORNL	1,220,000	0	101,400	100,000	261,900	756,700
96-E-300 Combustion Research Facility, Phase II, SNL	26,800	22,800	4,000	0	0	0
Total, Construction		22,800	105,400	100,000	261,900	756,700

Major Items of Equipment (TEC $2 million or greater)

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1999	FY 2000	FY 2001 Request	Accept-ance Date
Short Pulse Spallation Upgrade at LANSCE – LANL	20,500	4,500	4,500	3,500	4,500	FY 2002
HB-2 Beam Tube Extension at HFIR - ORNL	5,550	0	2,800	1,600	1,150	FY 2001
SPEAR3 Upgrade	29,000[a]	0	0	0	8,000	FY 2003
ALS Beamline	6,000	0	1,500	750	1,800	FY 2003
Total, Major Items of Equipment		4,500	8,800	5,850	15,450	

[a] DOE portion only; total estimated Federal cost, including NIH funding (beginning in FY 1999), is $58,000,000.

99-E-334 - Spallation Neutron Source, Oak Ridge National Laboratory, Oak Ridge, Tennessee

(Changes from FY 2000 Congressional Budget Request are denoted with a vertical line in the left margin.)

The Total Estimated Cost and Total Project Cost have been increased and the construction schedule has been extended as a result of project restructuring during FY 1999 and the FY 2000 appropriation that was $96,100,000 less than the FY 2000 request.

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 1999 Budget Request (*Preliminary Estimate)*	1Q 1999	4Q 2003	3Q 2000	4Q 2005	1,138,800	1,332,800
FY 2000 Budget Request	1Q 1999	4Q 2003	3Q 2000	1Q 2006	1,159,500	1,360,000
FY 2001 Budget Request (*Current Estimate*)	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,220,000	1,440,000

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Construction			
1999	101,400	101,400	37,140
2000	100,000	100,000	133,960
2001	261,900	261,900	249,900
2002	290,200	290,200	289,100
2003	222,400	222,400	224,400
2004	131,400	131,400	142,800
2005	81,600	81,600	91,600
2006	31,100	31,100	51,100

3. Project Description, Justification and Scope

The purpose of the Spallation Neutron Source (SNS) Project is to provide a next-generation short-pulse spallation neutron source for neutron scattering and related research in broad areas of the physical, chemical, materials, biological, and medical sciences. The SNS will be a national facility with an open user policy attractive to scientists from universities, industries, and federal laboratories. It is anticipated that the facility will be used by 1,000-2,000 scientists and engineers each year and that it will meet the national need for neutron science capabilities well into the 21st century. Neutrons enable scientists studying the physical, chemical, and biological properties of materials to determine how atoms and molecules are arranged and how they move. This is the microscopic basis for the features that make materials of technological significance for information technology, transportation, pharmaceuticals, magnetic, and many other economically important areas.

The importance of neutron science for fundamental discoveries and technological development is universally acknowledged. The scientific justification and need for a new neutron source and instrumentation in the U.S. have been thoroughly established by numerous studies by the scientific community since the 1970s. These include the 1984 National Research Council study *Major Facilities for Materials Research and Related Disciplines* (the Seitz-Eastman Report), which recommended the immediate start of the design of both a steady-state source and an accelerator-based pulsed spallation source. More recently, the 1993 DOE Basic Energy Sciences Advisory Committee (BESAC) report *Neutron Sources for America's Future* (the Kohn Panel Report) again included construction of a new pulsed spallation source with SNS capabilities among its highest priorities. This conclusion was even more strongly reaffirmed by the 1996 BESAC Report (the Russell Panel Report), which recommended the construction of a 1 megawatt (MW) spallation source that could be upgraded to significantly higher powers in the future.

Neutrons are a unique and increasingly indispensable scientific tool. Over the past decade, they have made invaluable contributions to the understanding and development of many classes of new materials, from high temperature superconductors to fullerenes, a new form of carbon. In addition to creating the new scientific knowledge upon which unforeseen breakthroughs will be based, neutron science is at the core of many technologies that currently improve the health of our citizenry and the safety and effectiveness of our industrial materials.

The information that neutrons provide has wide impacts. For example, chemical companies use neutrons to make better fibers, plastics, and catalysts; drug companies use neutrons to design drugs with higher potency and fewer side effects; and automobile manufacturers use the penetrating power of neutrons to understand how to cast and forge gears and brake discs in order to make cars run better and more safely. Furthermore, research on magnetism using neutrons has led to higher strength magnets for more efficient electric generators and motors and to better magnetic materials for magnetic recording tapes and computer hard drives.

Based on the recommendations of the scientific community obtained via the Russell Panel Report, the SNS has been designed to operate at an average power on target of about at least 1 megawatt (MW); the current design will produce an approximately 2 MW machine.. At this power level, the SNS will be the most powerful spallation source in the world--more than ten times that of ISIS at the Rutherford Laboratory in the United Kingdom. Furthermore, SNS will be positioned to take advantage of new technologies to permit upgrades to substantially higher power as they become available. Thus, the SNS will be the nation's premiere neutron facility for many decades.

The importance of high power, and consequently high neutron flux (i.e., high neutron intensity), cannot be overstated. The properties of neutrons that make them an ideal probe of matter also require that they be generated with high flux. (Neutrons are particles with the mass of the proton, with spin 1/2, and with no electrical charge.) Neutrons interact with nuclei and magnetic fields; both interactions are extremely weak, but they are known with great accuracy. Because they have spin, neutrons have a magnetic moment and can be used to study magnetic structure and magnetic properties of materials. Because they weakly interact with materials, neutrons are highly penetrating and can be used to study bulk phase samples, highly complex samples, and samples confined in thick-walled metal containers. Because their interactions are weak and known with great accuracy, neutron scattering is far more easily interpreted than either photon scattering or electron scattering. However, the relatively low flux of existing neutron sources and the small fraction of neutrons that get scattered by most materials means most measurements are limited by the source intensity.

The pursuit of high-flux neutron sources is more than just a desire to perform experiments faster, although that, of course, is an obvious benefit. High flux enables broad classes of experiments that cannot be done with low-flux sources. For example, high flux enables studies of small samples, complex molecules and structures, time-dependent phenomena, and very weak interactions. Put most simply, high flux enables studies of complex materials in real time and in all disciplines--physics, chemistry, materials science, geosciences, and biological and medical sciences.

The SNS will consist of a linac-ring accelerator system that delivers short (microsecond) pulses to a target/moderator system where neutrons are produced by a nuclear reaction process called spallation. The process of neutron production in the SNS consists of the following: negatively charged hydrogen ions are produced in an ion source and are accelerated to 1 giga electron volt (GeV) energy in a linear accelerator (linac); the hydrogen ion beam is injected into an accumulator ring through a stripper foil, which strips the electrons off of the hydrogen ions to produce a proton beam; the proton beam is collected and bunched into short pulses in the accumulator ring; and, finally, the proton beam is injected into a heavy metal target at a frequency of up to 60 Hz. The intense proton bursts striking the target produce pulsed neutron beams by the spallation process. The high-energy neutrons so produced are moderated (i.e., slowed down) to reduce their energies, typically by using thermal or cold moderators. The moderated neutron beams are then used for neutron scattering experiments. Specially designed scientific instruments use these pulsed neutron beams for a wide variety of investigations.

The primary objectives in the design of the site and buildings for the SNS are to provide optimal facilities for the DOE and the scientific community for neutron scattering well into the 21st century and to address the mix of needs associated with the user community, the operations staff, security, and safety.

A research and development program is required to ensure technical feasibility and to determine physics design of accelerator and target systems that will meet performance requirements.

The objectives stated above will be met by the technical components described earlier (ion source; linac accelerator; accumulator ring; target station with moderators; beam transport systems; and experimental facilities capable of supporting up to 18 neutron scattering beam lines for research instruments) and attendant conventional facilities. Also included on the site will be facilities to support the needs of operations staff, technical support staff, users and capabilities for remote servicing of activated components. An initial suite of approximately 10 neutron scattering instruments is included in the TEC.

The FY 2000 budget authority provided for completing most preliminary (Title I) design activities and starting detailed (Title II) design, construction site preparation, long-lead hardware procurement, and continued critical research and development work necessary to reduce technical and schedule risks.

FY 2001 funding of $281,000,000 (includes other project costs) is requested for the SNS Project for conducting detailed (Title II) design and starting fabrication of the ion source, low-energy beam transport, linac structure and magnet systems, target assemblies, experimental instruments, and global control systems. Construction will begin on several conventional facilities such as the front end building, linac tunnel, ring-service building, and the klystron hall. Construction will be completed on roads into the site and site preparation. Production will continue on several significant equipment items such as magnets, target systems, and klystrons.

Project management and integration activities, which are exceptionally important during this phase of the project, will also be conducted. Work will continue on the Safety Assessment Document for all the facility except for the target system, for which a Safety Analysis Report will be prepared.

4. Details of Cost Estimate

(dollars in thousands)

	Current Estimate	Previous Estimate
Design and Management Costs		
Engineering, design and inspection at approximately 10% of construction costs	127,100	166,900
Construction management at approximately 1% of construction costs	15,400	26,300
Project management at approximately 11% of construction costs	135,200	102,900
Land and land rights	0	0
Construction Costs		
Improvements to land (grading, paving, landscaping, and sidewalks)	27,100	28,600
Buildings	151,800	176,700
Other structures	600	600
Utilities (electrical, water, steam, and sewer lines)	25,800	30,500
Technical Components	433,200	417,900
Standard Equipment	2,700	1,100
Major computer items	7,600	12,000
Removal cost less salvage	0	0
Design and project liaison, testing, checkout and acceptance	5,200	9,700
Subtotal	931,700	973,200
Contingencies at approximately 31 percent of above costs	288,300	186,300
Total Line Item Cost	1,220,000	1,159,500
Less: Non-Agency Contribution	0	0
Total, Line Item Costs (TEC)	1,220,000	1,159,500

5. Method of Performance

The SNS project is being carried out by a partnership of five DOE national laboratories, led by ORNL, as the prime contractor to DOE. The other four laboratories are Argonne, Brookhaven, Lawrence Berkeley, and Los Alamos National Laboratories. Each laboratory is assigned responsibility for accomplishing a well defined portion of the project's scope that takes advantage of their technical strengths: Argonne - Instruments; Brookhaven - Accumulator Ring; Lawrence Berkeley - Front End; Los Alamos - Linac; Oak Ridge - Target. Project execution is the responsibility of the SNS Project Director with the support of a central SNS Project Office at ORNL, which provides overall project management, systems integration, ES&H, quality assurance, and pre-commissioning support. The SNS Project Director has prime authority for directing the efforts at all five partner laboratories and exercises ultimate financial control over all project activities. The ORNL Management and Operating Contractor has subcontracted to an Industry Team for design and construction management services. The Industry Team consists of an Architect-Engineer for the conventional facilities design and a Construction Manager for construction installation, equipment procurement, testing and pre-operational support. Procurements by all five laboratories will be accomplished, to the extent feasible, by fixed price subcontracts awarded on the basis of competitive bidding.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 1999	FY 2000	FY 2001	Outyears	Total
Project Cost						
Facility Cost [a]						
Line Item TEC	0	37,140	133,960	249,900	799,000	1,220,000
Plant Engineering & Design	0	0	0	0	0	0
Expense-funded equipment	0	0	0	0	0	0
Inventories	0	0	0	0	0	0
Total direct cost	0	37,140	133,960	249,900	799,000	1,220,000
Other project costs						
R&D necessary to complete project [b]	21,600	26,837	16,820	16,000	14,097	95,354
Conceptual design cost [c]	15,303	0	0	0	0	15,303
Decontamination & Decommissioning (D&D)	0	0	0	0	0	0
NEPA Documentation costs [d]	1,500	400	0	0	0	1,900
Other project-related costs [e]	0	800	900	3,000	101,700	106,400
Capital equipment not related construction [f]	100	563	180	100	100	1,043
Total, Other project costs	38,503	28,600	17,900	19,100	115,897	220,000
Total project cost (TPC)	38,503	65,740	151,860	269,000	914,897	1,440,000

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a Construction line item costs included in this budget request are for providing Title I and II design, inspection, procurement, and construction of the SNS facility for an estimated cost of $1,220,000,000.

b A research and development program at an estimated cost of $95,354,000 is needed to confirm several design bases related primarily to the accelerator systems, the target systems, safety analyses, cold moderator designs, and neutron guides, beam tubes, and instruments. Several of these development tasks require long time durations and the timely coupling of development results into the design is a major factor in detailed task planning.

c Costs of $15,303,000 are included for conceptual design and for preparation of the conceptual design documentation prior to the start of Title I design in FY 1999.

d Estimated costs of $1,900,000 are included to complete the Environmental Impact Statement.

e Estimated costs of $106,400,000 are included to cover pre-operations costs.

f Estimated costs of $1,043,000 to provide test facilities and other capital equipment to support the R&D program.

7. Related Annual Funding Requirements

	(FY 2000 dollars in thousands)	
	Current Estimate	Previous Estimate
Facility operating costs	21,300	N/A
Facility maintenance and repair costs	25,300	N/A
Programmatic operating expenses directly related to the facility	22,500	N/A
Capital equipment not related to construction but related to the programmatic effort in the facility	2,100	N/A
GPP or other construction related to the programmatic effort in the facility	1,000	N/A
Utility costs	30,400	N/A
Accelerator Improvement Modifications (AIMs)	4,100	N/A
Total related annual funding	106,700	N/A

Advanced Scientific Computing Research

Program Mission

The primary mission of the Advanced Scientific Computing Research (ASCR) program, which is carried out by the Mathematical, Information, and Computational Sciences subprogram, is to discover, develop, and deploy the computational and networking tools that enable researchers in the scientific disciplines to analyze, model, simulate, and predict complex phenomena important to the Department of Energy. To accomplish this mission the program fosters and supports fundamental research in advanced scientific computing – applied mathematics, computer science, and networking – and operates supercomputer, networking, and related facilities. The applied mathematics research efforts provide the fundamental mathematical methods to model complex physical and biological systems. The computer science research efforts enable scientists to efficiently run these models on the highest performance computers available and to store, manage, analyze, and visualize the massive amounts of data that result. The networking research provides the techniques to link the data producers; e.g., supercomputers and large experimental facilities with scientists who need access to the data.

In fulfilling this primary mission the ASCR program supports the Office of Science Strategic Plan's goal of providing extraordinary tools for extraordinary science as well as building the foundation for the research in support of the other goals of the strategic plan. In the course of accomplishing this mission, the research programs of ASCR have played a critical role in the evolution of high performance computing and networks.

In addition to this primary mission, the ASCR program is also responsible for the Laboratory Technology Research subprogram in the Office of Science, whose mission is to foster and support high-risk research in the natural sciences and engineering in partnership with the private sector leading to innovative applications relevant to the Nation's energy sector.

The high quality of the research in the entire ASCR program, supporting both of its missions, is continuously evaluated through the use of merit-based peer review and scientific advisory committees.

Program Goals

- Maintain world leadership in areas of advanced scientific computing research relevant to the missions of the Department of Energy.
- Integrate the results of advanced scientific computing research into the natural sciences and engineering.
- Provide world-class supercomputer and networking facilities for scientists working on problems that are important to the missions of the Department.
- Integrate and disseminate the results of high-risk research in natural sciences and engineering to the private sector through the Laboratory Technology Research subprogram.

Program Objectives

- *Advance the frontiers of knowledge in advanced scientific computing research.* – Foster research to create a new fundamental knowledge in areas of advanced computing research important to the Department, e.g., high performance computing, high speed networks to support scientific collaborations, and software to enable scientists to make effective use of the highest performance computers available.

- *Apply advanced computing knowledge to complex problems of importance to DOE.* — Promote the transfer of the results of advanced scientific computing research to DOE missions in areas such as the improved use of fossil fuels including understanding the combustion process; the atmospheric and environmental impacts of energy production and use including global climate modeling and subsurface transport; and future energy sources including fusion energy as well as the fundamental understanding of matter and energy.
- *Plan, construct, and operate premier supercomputer and networking facilities.* — Serve researchers at national laboratories, universities, and industry, thus enabling both new understanding through analysis, modeling, and simulation of complex problems and effective integration of geographically distributed teams through national collaboratories.
- *Transfer results of fundamental research to the private sector.* — Provide tangible results of research and development activities through cost-shared partnerships with industry.

Performance Measures

The Advanced Scientific Computing Research program measures performance in various ways, depending on the objective. However, performance measures fall into four broad categories:

- peer review, which is the key performance measurement process of all research activities;
- indicators or metrics (i.e., things that can be counted);
- customer evaluation and stakeholder input; and
- qualitative assessments, which might include historical retrospectives and annual program highlights.

Facility performance measures include achievement of performance specifications, operating time, throughput, user satisfaction, and effective utilization of resources as determined by reports from external review panels, user steering committees, and internal Office of Science (SC) program manager committees. In addition, ASCR supercomputer and network facilities have periodic external performance reviews. The Energy Sciences Network (ESnet) operations and management were reviewed in this manner in FY 1998.

Performance Measures for FY 2001 include:

- conduct regular peer review and merit evaluation based on the principles set down in 10 CFR Part 605 for grants and cooperative agreements, with all research projects reviewed at least once and no project extending more than four years without review;
- support the Computational Science Graduate Fellowship Program with the successful appointment of 10 new students to support the next generation of leaders in computational science for DOE and the Nation;
- the operating time lost at scientific facilities due to unscheduled NERSC/ESnet downtime will be less than 10 percent of the total scheduled possible operating time, on average;
- facilities, including the National Energy Research Scientific Computing Center (NERSC) and ESnet, will be operated within budget and successfully meet user needs and satisfy overall SC program requirements where, specifically, NERSC will deliver 3.6 Teraflop capability by the end of FY 2001 to support DOE's science mission;
- work performed by investigators supported by ASCR will continue to be recognized as outstanding through the receipt of major prizes and awards;
- the Laboratory Technology Research subprogram will complete its review of projects initiated during the previous year to ensure that research objectives and program goals are being met;

- research in predictability of computer simulations will provide a common intellectual foundation and a set of tools for evaluating predictability issues. These tools will be used by initiatives to use computational simulation across the Department, including climate research, combustion modeling, and stockpile stewardship.
- the Advanced Computing Research Facilities program will provide new insights into the usefulness of novel high performance computing architectures for science.
- complete reviews on Laboratory Technology Research portfolio (1) to ensure that satisfactory progress has been made toward stated objectives and (2) to assess the scientific quality of the research performed to date.

Significant Accomplishments and Program Shifts

The FY 2001 budget includes substantial enhancements to our research portfolio to build the next generation of high performance computing and communications tools to support the missions of the Office of Science and the Department of Energy in the next century. Increased funding in the areas of advanced scientific computing will be described in more detail in the Mathematical, Information, and Computational Sciences subprogram section.

A new Federally-chartered advisory committee has been established for the Advanced Scientific Computing Research program and has been charged with providing advice on: promising future directions for advanced scientific computing research; strategies to couple advanced scientific computing research in other disciplines; and the relationship of the DOE program to other Federal investments in information technology research. This advisory committee will play a key role in evaluating future planning efforts for research and facilities.

The ASCR program builds on decades of leadership in high performance computing. Some of the pioneering accomplishments of this program are:

Mathematical, Information, and Computational Sciences (MICS)

- **Established First National Supercomputer Center.** In 1974, DOE established the National Magnetic Fusion Energy Computing Center [the predecessor to the National Energy Research Scientific Computing Center (NERSC)], and pioneered the concept of remote, interactive access to supercomputers. Before this time, scientists using supercomputers had to travel to the location of the computer to make use of it. In addition, users were only able to use these computers by submitting jobs and waiting for hours or days to see the output. The Mathematical, Information, and Computational Sciences (MICS) subprogram developed the first interactive operating system for supercomputers, Cray Time Sharing System (CTSS), as well as a nationwide network to allow remote users to have effective access to the computers. This operating system revolutionized access to supercomputers by enabling users to monitor their jobs as they executed. When the National Science Foundation (NSF) initiated its Supercomputer Centers program in the 1970's, the CTSS operating system was adopted by the San Diego Supercomputing Center and the National Center for Supercomputing Applications to enable users to access NSF's first CRAY machines.
- **Laid Mathematical Foundations for High Performance Computing: Numerical Linear Algebra Libraries.** Today's high performance scientific computations rely on high performance, efficient libraries of numerical linear algebra software. These libraries, which are the core of

numerical efforts in the solution of differential and integral equations LINPACK, EISPAC, LAPACK, SCALAPACK are the direct result of decades of DOE funding of basic research in this area. These libraries are used by thousands of researchers worldwide and are a critical part of the world's scientific computing infrastructure.

- **Developed High Speed Interconnects for Supercomputers: High Performance Parallel Interface (HiPPI).** In order to develop a standard interface between supercomputers and other devices, such as disk arrays and archival tape systems, and visualization computers, DOE laboratories developed the high performance network interface (HiPPI) and led a consortium of vendors to make it the industry standard for the highest bandwidth interconnects between computers and peripheral devices. This advance required the solution of many problems in high speed signaling, data parallelism and high speed protocol design had to be understood to enable this advance.
- **Led the Transition to Massively Parallel Supercomputing: Parallel Virtual Machine (PVM) and Message Passing Interface (MPI).** DOE researchers developed PVM and MPI to enable scientists to make effective use of networks of workstations and massively parallel computers. Both of these software packages have become standards in the industry and are implemented by virtually all of the high performance computer manufacturers in the world. Both of these developments were enabled by over a decade of basic research in message passing and distributed computing supported by DOE along with many experiments to apply these techniques to real scientific problems.
- **Contributed to the Development of the Internet: Slow Start Algorithm for the Transmission Control Protocol (TCP).** Transmission Control Protocol (TCP) part of TCP/IP (Internet Protocol) is responsible for ensuring that packets arrive at their destination. In 1987, as DOE and the other Federal agencies were interconnecting their networks to form the core of the Internet, critical parts of the infrastructure began to fail. There was concern that this represented a fundamental flaw in the TCP/IP architecture; however, a researcher at LBNL applied ideas from fluid flow research to understand the problem and develop a solution. This new TCP algorithm was incorporated in virtually every commercial version of Internet software within six months and enabled the Internet to scale from a small research network to today's worldwide infrastructure.

Building on this long history of accomplishments, principal investigators of the Advanced Scientific Computing Research program this year received recognition through numerous prizes, awards, and honors. A sample of the significant accomplishments and awards produced by the program this year is given below.

Mathematical, Information, & Computational Sciences

- **Parallel Computational Oil Reservoir Simulator.** To meet the Nation's energy needs, the United States oil and gas industry must continue to advance the technology used to extract oil and gas from both new and old fields. Until recently, most drilling and recovery activities were based on past practices that often lacked a sound scientific basis. Computer scientists at Argonne National Laboratory, in collaboration with petroleum engineers at the University of Texas at Austin, have recently developed a software package capable of simulating the flow of oil and gas in reservoirs. These codes, which are based on software tools designed at Argonne, are able to run on a variety of computer platforms, including massively parallel systems with hundreds and even thousands of processors. The software codes will enable the oil and gas industry to lower exploration and drilling costs and enhance the yield of oil from new and old fields alike.
- **Predictability Research Program.** Understanding the behavior of solids, liquids and gases under extreme conditions of temperature and pressure is often the key to understanding complex physical

systems that are critical to a number of the missions of the Department of Energy. The physical conditions under which the devices operate are often so extreme that it is not possible to perform laboratory experiments to validate the design of the devices. Faced with such limitations scientists and engineers are turning more and more to the use of high-speed computers to simulate the behavior of matter under conditions that are not amenable to experimental verification. Under funding from the new MICS Predictability research program a multidisciplinary team of researchers from the Los Alamos and Sandia National Laboratories has performed highly accurate simulations of shockwave-induced fluid instabilities (that are known as Richtmyer-Meshkov instabilities). The simulations match results from "gas-curtain" experiments also conducted by the team over several physically important parameter ranges that can be measured in the laboratory. Researchers are now computationally exploring the behavior of real systems in crucial parameter ranges that are outside of experimental verifiability. This work has broad applicability to our ability to simulate advanced fluid and combustion systems.

- **Theory of Nonequilibrium Solids.** The melting of solids into liquids is a very common, but poorly understood phenomenon that appears in a host of scientific and engineering problems of importance to the Department of Energy. With the appearance of high speed computers in recent years, scientists have been able to couple simulation to theoretical and experimental investigations of melting phenomena, resulting in advances in our understanding of the underlying physics and material properties of solids undergoing melting. An applied mathematician and a materials scientist at the Oak Ridge National Laboratory discovered three distinct "hidden structures" in the melting of two-dimensional materials. This totally unexpected finding has awakened interest among theorists, and it has set off an intense search for additional structures in both two- and three-dimensional problems. This fundamental discovery was enabled by coupling the expertise of the applied mathematician in numerical methods, the expertise of the materials scientist in developing the equations to describe the system, and access to significant high performance computing resources.
- **High Performance Algorithms for Scientific Simulation.** Many problems in science and engineering involve the complex interplay of forces and effects on different time and length scales. Two significant examples of such nonlinear multi-time, multi-scale phenomena are the interaction of the atmosphere and the oceans in the creation of the global climate and the burning of fossil fuels in engines and other devices. The size and complexity of such problems require the development of fast and efficient algorithms and software that can take advantage of the resolution power of today's massively parallel computing platforms. Applied mathematicians at the Lawrence Berkeley National Laboratory, working in collaboration with applied mathematicians at the Lawrence Livermore National Laboratory and New York University, have developed adaptive mesh refinement algorithms capable of automatically redistributing grid points in computational regions where significant physics is occurring over small time scales. At finer and finer length scales the continuous flow solver is replaced by a particle method such as Monte Carlo, thus allowing the researchers to accurately resolve phenomena over a broad range of length and time scales. Applications of this work to the Accelerated Strategic Computing Initiative (ASCI) and Office of Science problems are many, although the primary focus of the research is the accurate simulation of diesel combustion in realistic, three-dimensional geometries. The laboratory and academic researchers are working on this project closely with engineers from Caterpillar and Cummins.
- **Real-time Reconstruction of Microtomographic Data at the Advanced Photon Source.** The use of X-rays as a non-destructive tool for investigating the internal structure of materials at the micron length scale has grown rapidly over the last decade due to the advent of synchrotron radiation sources such as the Advanced Photon Source (APS). Unfortunately, while advanced detector technology now allows gigabytes of data to be collected in tens of minutes, the computing technologies required to translate this data into images and hence insight have not kept pace. Recent

work at Argonne National Laboratory and the University of Southern California's Information Sciences Institute (ISI) has produced new techniques that overcome this problem. By using a combination of high-performance networking and computing resources, parallel reconstruction algorithms, and advanced resource management, communication, and collaboration software, the Argonne/ISI team was able to demonstrate quasi-real-time 3-D imaging of samples of an APS tomographic beamline. The results as demonstrated in a live run in early May 1999, are stunning: ten minutes after data collection starts, an initial 3-D image appears on the screens of project scientists both at Argonne and at other institutions. Over the next 20 minutes, this image is progressively refined as more data is obtained. For the first time, scientists can change experimental parameters in the middle of an experiment. The implications for better use of scarce facilities and for higher-quality science are clear. This new capability was made possible by support from the ASCR Grand Challenge program and by the parallel computers of Argonne's Center for Computational Science and Technology; it also makes extensive use of distributed computing and collaboration technologies developed under the DOE2000 computing program.

- **Pacific Northwest National Laboratory Researchers Win Best Paper Award at Supercomputing '98.** A paper authored by scientists from DOE's Pacific Northwest National Laboratory entitled, "An Out-of-Core Implementation of the COLUMBUS Massively-Parallel Multireference Configuration Interaction Program" received the Best Application Paper and the Best Overall Paper awards at the Supercomputing '98 conference on November 12, 1998, in Orlando, FL. The paper describes a novel parallelization approach developed to enable COLUMBUS, a legacy chemistry application, to be run efficiently on massively parallel computer platforms rather than the vector supercomputers for which it was originally written. This work was accomplished using Global Arrays, one of the DOE2000 Advanced Computational Testing and Simulation (ACTS) tools supported by MICS. Global Arrays provide a portable shared-memory programming environment optimized for the nonuniform memory hierarchy of modern computer architectures. The chemistry part of this project was supported by the MICS subprogram under the Phase II Grand Challenge program.
- **Argonne Researchers Win "Best of Show" Award at Supercomputing '98.** A team of Argonne scientists and their collaborators received the High-Performance Computing Challenge "best of show" award at the Supercomputing '98 conference for their work on innovative wide-area applications using the GUSTO high-performance distributed grid testbed. GUSTO (Globus Ubiquitous Supercomputing Testbed Organization) is a prototype for future computational grids that will link supercomputers, scientific instruments, virtual reality environments, and data archives transparently. It uses software developed by the Globus project, a multi-institutional collaborative project centered at Argonne and the University of Southern California's Information Science Institute funded by ASCR.
- **Supercomputing (SC'99) Awards.** Special awards were given to scientists from Argonne National Laboratory and University of Chicago for their achievements in simulating incompressible flows and another special award was given to a team of scientists from NASA and DOE laboratories for their achievements in fluid dynamics simulations.
- **TelePresence Microscopy Video Wins the Prestigious Crystal Award of Excellence.** The TelePresence Microscopy project that is part of the DOE2000 program at Argonne National Laboratory's (ANL) Material Sciences Division and is jointly funded by the Department's Mathematical, Information, and Computational Sciences subprogram and the Basic Energy Sciences program, both part of the Office of Science, has won the Prestigious Communicator's "Crystal Award of Excellence." The video was produced in collaboration with ANL's Materials Science Division, the National Institute of Standards and Technology, and Texas Instruments. The video was also funded under the auspices of the "IDEA" program at Texas Instruments and the Office of

MicroElectronics programs at the National Institute of Standards and Technology. The Communicator's Award is a national competition founded by communications professionals to recognize individuals and companies in the communications field whose talent and creativity achieves a high standard of excellence and serves as a standard for the industry.

- **The Maxwell Prize.** A new international prize in applied mathematics, the Maxwell Prize, has been awarded for MICS supported research at the Applied Mathematics Research program at Lawrence Berkeley National Laboratory. The research involved analysis of problems dominated by complexity, such as turbulence, failure and cracks in solids, flow in porous and inhomogeneous media, and combustion. The work on crack formation provided some of the basic tools used today in failure analysis, especially failure due to fatigue.

Laboratory Technology Research (LTR)

The LTR subprogram received five R&D-100 Awards in 1999 for the following research:

- Argonne National Laboratory, in collaboration with the Association of American Railroads and the Electro-Motive Division of General Motors, has developed a technology that should allow diesel engines to operate more cleanly and efficiently. The technology simultaneously minimizes emission of fine-particle pollution and oxides of nitrogen during combustion. It has been demonstrated in a locomotive diesel, but should apply to all types of diesel engines, including those in trucks, buses, heavy equipment, and cars. Practical and less expensive than alternative technologies, it could end a long-standing struggle with diesel pollution.
- Brookhaven National Laboratory, in collaboration with W.R. Grace, has developed the first product capable of destroying asbestos in installed fireproofing on building columns and beams without reducing the fire-resistive performance of the fireproofing material. The new technique, which is now commercially available, uses a foamy solution sprayed directly onto asbestos-containing fireproofing. The foam chemically digests nearly all of the asbestos fibers, dissolving them into harmless minerals. After being treated, the fireproofing is no longer a regulated material. The new process produces essentially no waste and is expected to save building owners the expense of disposing of regulated waste materials.
- Oak Ridge National Laboratory (ORNL), in collaboration with Minnesota Mining and Manufacturing (3M), has developed a new route to the fabrication of high temperature superconducting (HTS) wires for high power applications. These HTS materials have tremendous potential for greatly improved energy efficiency in a number of power applications related to the utilization of electric energy.
- Pacific Northwest National Laboratory (PNNL), in collaboration with DuPont, has developed a suite of programs for massively parallel computing platforms called the "Molecular Sciences Software Suite (MS3)." The new code has been successful in a number of applications to complex problems in the chemical and biochemical sciences. DuPont has used the technology to study the photochemistry of polymeric and agrochemical systems and for rational design of new dyes.
- PNNL, in collaboration with Finnegan MAT, has developed a novel source for enhanced ion detection. The "electrodynamic ion funnel" focuses ions in gases, greatly improving the sensitivity of analytical devices, such as mass spectrometers, that depend on ion formation and transfer in gases. The concept provides a major breakthrough in the field of electrospray mass spectrometry, which will impact fundamental studies in the biological, chemical, and environmental sciences.

In addition to the R&D-100 Awards, six scientists supported by the LTR subprogram were recipients of the following distinguished awards in 1999:

- A Genius Grant from the MacArthur Foundation for development of a method for tricking cells into expressing non-natural sugars on their surface.

- The 39th Annual G.H.A. Clowes Memorial Award for development of therapeutic approaches to breast cancer.
- The American Physical Society's James C. McGroody Prize for innovations in the growth of diamond and germanium crystals.
- The Humboldt Research Award for work on "lab-on-a-chip" micro devices, capable of carrying out chemical measurements normally performed in a conventional laboratory.
- A Federal Laboratory Consortium Award for work on microbiologically influenced corrosion in industrial environments.
- A Presidential Early Career Award for Scientists and Engineers for development of materials and methods that substantially improve the effectiveness of non-thermal plasma technology in treating nitrogen oxide emissions from vehicles.

In FY 1999, the Laboratory Technology Research subprogram initiated a portfolio of Rapid Access Projects that address research problems of small businesses by utilizing the unique facilities of the Office of Science laboratories. These projects were selected on the basis of scientific, technical and potential commercial merit, using competitive external peer review.

Advanced Energy Projects (AEP)

The Advanced Energy Projects subprogram was terminated in FY 2000.

Scientific Facilities Utilization

The ASCR program request includes $32,278,000 in FY 2001 to support the National Energy Research Scientific Computing (NERSC) Center. This investment will provide computer time for about 2,000 scientists in universities, federal agencies, and U.S. companies. It will also leverage both federally and privately sponsored research, consistent with the Administration's strategy for enhancing the U.S. National science investment. The proposed funding will enable NERSC to maintain its role as the Nation's largest, premier unclassified computing center, which is a critical element in the success of many SC research programs. Research communities that benefit from NERSC include structural biology; superconductor technology; medical research and technology development; materials, chemical, and plasma sciences; high energy and nuclear physics; and environmental and atmospheric research.

Taking The Next Steps in Scientific Computing, Networking, and Collaboration

The accomplishments of the MICS subprogram in scientific computing and enabling distributed scientific teams to work together were described in the ASCR program mission section above. However, additional investments will be required to enable DOE to take the next steps in scientific simulation and to address the challenges that it faces in simulating the complex multidisciplinary phenomena that lie at the heart of its missions. These investments focus on software issues that must be addressed to support today's high performance computers and future computers with significantly higher performance and complexity. They include funding for existing multi-teraflop computers; geographically-dispersed teams of disciplinary scientists, computer scientists, and applied mathematicians; and the supporting infrastructure. Therefore, in FY 2001 the MICS subprogram will enhance its efforts to produce the scientific computing, networking and collaboration tools that DOE researchers will require to address the scientific challenges of the next decade. These enhancements build on the historic strength of the Department of Energy in computational science, computer science, applied mathematics, and high-performance computing and in the design, development, and management of large scientific and engineering projects and scientific user facilities. They also take full advantage of the dramatic increases in computing capabilities being fostered by the *Accelerated Strategic Computing Initiative* (*ASCI*) in the Office of Defense Programs.

Scientific Computing

During the past quarter century computational simulation has dramatically advanced our understanding of the fundamental processes of nature and has been used to gain insights into the behavior of such complex natural and engineered systems as the earth's climate and automobile design. The new generation of terascale computing tools, and the 1,000 times more powerful petascale computing capabilities that are now on the horizon, will enable scientists to dramatically improve their understanding of the fundamental processes in many areas. In addition, these new tools will enable scientists to predict the behavior of many complex natural and engineered systems from a knowledge of the underlying physical, chemical, and biological processes involved. This new capability, to predict the behavior of complex systems based on the properties of their components, will change the way DOE and other government agencies solve their most demanding, mission-critical problems. A workshop held at the National Academy of Sciences in July 1998 identified opportunities for new scientific discovery through advanced computing in all of the programs of the Office of Science. The proposed investments to provide programs in computational biology, materials science, chemistry, climate modeling, fusion energy, and high energy and nuclear physics to realize some of these opportunities are discussed in the budgets of those programs.

However, success in those programs depends on investments in applied mathematics and computer science to provide the algorithms, mathematical libraries, and underlying computer science tools to enable the scientific disciplines to make effective use of terascale computers. Despite considerable progress during the past ten years in making massively parallel computer systems usable for applications, much remains to be done. The next generation computer systems to enable leading-edge applications will have between 5,000 and 10,000 individual computer processors rather than the 500-1,000 processors in today's typical high performance systems. In addition, the internal structure of the computers will become more complex as computer designers are forced to introduce more layers of memory hierarchy to maintain performance and develop new hardware features to support rapid communication and synchronization. The end result five years from now will be hardware systems that, while having their roots in today's systems, will be substantially different and substantially more complex and therefore more challenging to exploit for high performance. These challenges will require substantial improvements in parallel computing tools, parallel I/O (input/output) systems, data management, algorithms, and program libraries that must work together as an integrated software system. In addition to the fundamental research challenges that are implied by this evolution in computer hardware, DOE must integrate the output from successful MICS-supported research projects into integrated sets of software tools that scientists in disciplines such as global climate, materials sciences, or computational biology can build on to address scientific challenges.

The MICS subprogram will address these challenges by establishing a small number of competitively selected partnerships (based on a solictation notice to labs and universities) focused on discovering, developing, and deploying to scientists key enabling technologies. These partnerships, which will be called enabling technology centers, must support the full range of activities from basic research through deployment and training because the commercial market for software to support terascale scientific computers is too small to be interesting to commercial software providers. These centers will build on the successful experience of the MICS subprogram in managing the DOE2000 initiative, as well as on the lessons learned in important programs supported by DARPA such as Project Athena at MIT, the Berkeley Unix Project, and the initial development of the Internet software and the Internet Activities Board (IAB). These enabling technology centers will have close ties to key scientific applications projects to ensure their success.

Networking and Collaboration

Advances in network capabilities and network-based technologies now make it possible for large geographically-distributed teams to effectively collaborate. This is especially important for the teams using the major experimental facilities, computational resources, and data resources supported by DOE. With leadership from DOE, these geographically distributed laboratories or collaboratories have begun to play an important role in the Nation's scientific enterprise. The importance of collaboratories is expected to increase in the future. However, significant research questions must be addressed if collaboratories are to achieve their potential: to enable remote access to petabyte/year High Energy and Nuclear Physics (HENP) facilities such as the Relativistic Heavy Ion Collider (RHIC) to be the same as "being there;" to provide remote visualization of terabyte to petabyte data sets from computational simulation; and to enable effective remote access to tomorrow's advanced scientific computers.

- First, new capabilities are required in the nationwide scientific networks to support collaboratories. For example, using the current Internet, it would take about 2,500 hours to transmit one day's data from RHIC to one remote site for analysis. Typical RHIC experimental collaborations involve thousands of scientists and hundreds of institutions spread across the country and the world who need access to millions of gigabytes (petabytes) of data (a billion times as much data as a large web page). This situation is very different than data management in the commercial sector where millions of users are moving to web pages. Significant research is needed to enable today's commercial networks to be used for scientific data retrieval and analysis. This includes research on advanced protocols, special operating system services to support very high speed transfers, and advanced network control.
- Second, research is needed to understand how to integrate the large number of network devices, network-attached devices, and services that collaboratories require. Examples of the components and services that need to be integrated include: network resources, data archives on tape, high performance disk caches, visualization and data analysis servers, authentication and security services, and the computer on a scientist's desk. All of these physical and software services must be tied together by common software framework building blocks or "middleware" to enable the collaboratories of the future to succeed.

The MICS subprogram will address these challenges through an integrated program of fundamental research in networking and collaboratory tools, partnerships with key scientific disciplines, and advanced network testbeds.

Enhancements to Computing and Networking Facilities

To realize the scientific opportunities, enhancements to the Office of Science's computing and networking facilities are also required. The current computers at NERSC provide less than half of the computer resources that were requested last year. This pressure on the facility will only increase in future years as more applications become ready to move from testing the software to using the software to generate new science. In addition, as the speed of computers increases, the amount of data they produce also increases. Therefore, focused enhancements to the Office of Science's network infrastructure is required to enable scientists to access and understand the data generated by their software. These network enhancements are also required to allow researchers to have effective remote access to the experimental facilities that the Office of Science provides for the Nation.

Interagency Environment

The research and development activities supported by the MICS subprogram are coordinated with other Federal efforts through the Interagency Principals Group, chaired by the President's Science Advisor, and the Information Technology Working Group (ITWG). The ITWG represents the evolution of an interagency coordination process that began under the 1991 High Performance Computing Act as the High Performance Computing, Communications, and Information Technology (HPCCIT) Committee. DOE has been a key participant in these coordination bodies from the outset and will continue to coordinate its R&D efforts closely through this process.

In FY 1999, the President's Information Technology Advisory Committee (PITAC) recommended significant increases in support for basic research in: Software, Scalable Information Infrastructure, High End Computing, and Socio-Economic and Workforce Impacts, as well as support of research projects of broader scope and visionary "Expeditions to the 21st Century" to explore new ways that computing could benefit our world.

Although the focus of the enhanced DOE program is on solving mission critical problems in scientific computing, this program will make significant contributions to the Nation's Information Technology Basic Research effort just as previous DOE mission-related research efforts have led to DOE's leadership in this field. In particular, the enhanced MICS subprogram will place emphasis on software research to improve the performance of high-end computing as well as research on the human-computer interface and on information management and analysis techniques. In addition, through NERSC and the Advanced Computing Research Facilities, the enhanced MICS subprogram will provide the most powerful high-end computers available to the Nation's scientific and engineering communities.

Funding of Contractor Security Clearances

In FY 1999, the Department divided the responsibility for obtaining and maintaining security clearances. The Office of Security Affairs, which was responsible for funding all Federal and contractor employee clearances, now pays only for clearances of Federal employees, both at headquarters and the field. Program organizations are now responsible for contractor clearances, using program funds. This change in policy enables program managers to make the decisions as to how many and what level clearances are necessary for effective program execution. In this way, it is hoped that any backlog of essential clearances which are impeding program success can be cleared up by those managers most directly involved. The Office of Science is budgeting $47,000 for estimated contractor security clearances in FY 2000 and FY 2001 within this decision unit.

Workforce Development

The R&D Workforce Development mission is to ensure the supply of computational science and PhD level scientists for the Department and the Nation through graduate student and post doctoral research support. In FY 1999, this program will support 855 graduate students and post doctoral investigators, of which 500 will be supported at Science user facilities.

ASCR will continue the Computational Science Graduate Fellowship Program with the successful appointment of 10 new students to support the next generation of leaders in computational science.

Funding Profile

(dollars in thousands)

	FY 1999 Current Appropriation	FY 2000 Original Appropriation	FY 2000 Adjustments	FY 2000 Current Appropriation	FY 2001 Request
Advanced Scientific Computing Research					
Mathematical, Information, and Computational Sciences	135,364	123,000	-3,929	119,071	169,682
Laboratory Technology Research	15,721	9,000	-188	8,812	12,288
Advanced Energy Projects	2,427	0	0	0	0
Subtotal, Advanced Scientific Computing Research	153,512	132,000	-4,117	127,883	181,970
Use of Prior Year Balances	-1,573[a]	0	0	0	0
General Reduction	0	-2,694	2,694	0	0
Contractor Travel	0	-988	988	0	0
Omnibus Rescission	0	-435	435	0	0
Total, Advanced Scientific Computing Research	151,939[b]	127,883	0	127,883	181,970

Public Law Authorization:

Public Law 95-91, "Department of Energy Organization Act"

Public Law 103-62, "Government Performance Results Act of 1993"

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $3,735,000 which has been transferred to the SBIR program and $224,000 which has been transferred to the STTR program.

Funding by Site

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	15,206	11,873	10,560	-1,313	-11.1%
National Renewable Energy Laboratory	127	0	0	0	0.0%
Sandia National Laboratories	5,651	4,798	4,705	-93	-1.9%
Total, Albuquerque Operations Office	20,984	16,671	15,265	-1,406	-8.4%
Chicago Operations Office					
Ames Laboratory	2,239	1,672	1,571	-101	-6.0%
Argonne National Laboratory	19,032	12,187	11,958	-229	-1.9%
Brookhaven National Laboratory	2,023	1,811	1,504	-307	-17.0%
Fermi National Accelerator Laboratory	213	60	200	+140	+233.3%
Princeton Plasma Physics Laboratory	121	45	200	+155	+344.4%
Chicago Operations Office	19,746	11,001	10,265	-736	-6.7%
Total, Chicago Operations Office	43,374	26,776	25,698	-1,078	-4.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	57,969	53,865	64,457	+10,592	+19.7%
Lawrence Livermore National Laboratory	3,620	3,210	3,160	-50	-1.6%
Stanford Linear Accelerator Center	1,052	375	450	+75	+20.0%
Oakland Operations Office	5,176	2,474	2,179	-295	-11.9%
Total, Oakland Operations Office	67,817	59,924	70,246	+10,322	+17.2%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science and Education	169	20	20	0	0.0%
Oak Ridge National Laboratory	13,392	7,584	6,719	-865	-11.4%
Thomas Jefferson National Accelerator Facility	151	50	200	+150	+300.0%
Oak Ridge Operations Office	17	42	0	-42	-100.0%
Total, Oak Ridge Operations Office	13,729	7,696	6,939	-757	-9.8%
Richland Operations Office					
Pacific Northwest National Laboratory	4,312	2,602	2,210	-392	-15.1%
Washington Headquarters	3,296	14,214	61,612	+47,398	+333.5%
Subtotal, Advanced Scientific Computing Research	153,512	127,883	181,970	+54,087	+42.3%
Adjustment	-1,573[a]	0	0	0	0.0%
Total, Advanced Scientific Computing Research	151,939[b]	127,883	181,970	+54,087	+42.3%

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $3,735,000 which has been transferred to the SBIR program and $224,000 which has been transferred to the STTR program.

Site Description

Ames Laboratory

Ames Laboratory is a Multiprogram Laboratory located on 10 acres in Ames, Iowa. The MICS subprogram at Ames Laboratory conducts research in the materials scientific application pilot project, which focuses on applying advanced computing to problems in microstructural defects, alloys, and magnetic materials, and in computer science. The LTR subprogram at Ames conducts research in the physical, chemical, materials, mathematical, engineering, and environmental sciences through cost-shared collaborations with industry.

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. The MICS subprogram at ANL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. ANL also participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research facility. The Advanced Computing Research Facility (ACRF) at ANL focuses on advanced computers in the IBM-SP family of technologies as well as the interaction of those architectures with advanced visualization hardware. The LTR subprogram at ANL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are chemistry of ceramic membranes, separations technology, near-frictionless carbon coatings, and advanced methods for magnesium production.

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The LTR subprogram at BNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are materials for rechargeable lithium batteries, sensors for portable data collection, catalytic production of organic chemicals, and DNA damage responses in human cells.

Fermi National Accelerator Laboratory (Fermilab)

Fermilab is located on a 6,800-acre site about 35 miles west of Chicago, Illinois. The LTR subprogram at Fermilab conducts research in areas such as: superconducting magnet research, design and development, detector development and high-performance computing through cost-shared collaborations with industry.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory (LBNL) is a Multiprogram Laboratory located in Berkeley, California. The Laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. The MICS subprogram at LBNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. LBNL participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research facility. The Advanced Computing Research Facility (ACRF) at LBNL currently focuses on very large scale computing on hardware in the T3E architecture from SGI-Cray including issues of distributing jobs over all the processors efficiently and the associated system management issues. LBNL manages the Energy Sciences Network (ESnet). ESnet is one of the world's most effective and progressive science-related computer networks that provides worldwide access and communications to Office of Science (SC) facilities. In 1996, the National Energy Research Scientific Computing Center (NERSC) was moved from the Lawrence Livermore National Laboratory to LBNL. NERSC provides a range of high-performance, state-of-the-art computing resources that are a critical element in the success of many SC research programs. The LTR subprogram at LBNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are molecular lubricants for computers, advanced material deposition systems, screening novel anti-cancer compounds, and innovative membranes for oxygen separation.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on a 821 acre site in Livermore, California. The MICS subprogram at LLNL involves significant participation in the advanced computing software tools program as well as basic research in applied mathematics.

Los Alamos National Laboratory

Los Alamos National Laboratory (LANL) is a Multiprogram Laboratory located on a 27,000 acre site in Los Alamos, New Mexico. The Mathematical Information and Computational Sciences (MICS) subprogram at LANL conducts basic research in the mathematics and computer science and in advanced computing software tools. LANL also participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research facility. The Advanced Computing Research Facility (ACRF) at LANL focuses on a progression of technologies from SGI - Cray involving Origin 2000 Symmetric Multiprocessor Computers linked with HiPPI crossbar switches. This series of research computers has been given the name “Nirvana Blue.”

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on 150 acres in Oak Ridge, Tennessee. ORISE provides support for education activities funded within the ASCR program.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The MICS subprogram at ORNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools.

ORNL also participates in several scientific application and collaboratory pilot projects. The LTR subprogram at ORNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are high temperature superconducting wire, microfabricated instrumentation for chemical sensing, and radioactive stents to prevent reformation of arterial blockage.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The MICS subprogram at PNNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. PNNL also participates in several scientific application pilot projects. The LTR subprogram at PNNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are mathematical simulation of glass production, interactions of biological polymers with model surfaces, and characterization of micro-organisms in environmental samples.

Princeton Plasma Physics Laboratory

The Princeton Plasma Physics Laboratory (PPPL), a laboratory located in Plainsboro, New Jersey, is dedicated to the development of magnetic fusion energy. The LTR subprogram at PPPL conducts research in areas that include the plasma processing of semiconductor devices and the study of beam-surface interactions through cost-shared collaborations with industry.

Sandia National Laboratories

Sandia National Laboratories (SNL) is a Multiprogram Laboratory, with a total of 3,700 acres, located in Albuquerque, New Mexico, with sites in Livermore, California, and Tonapah, Nevada. The MICS subprogram at SNL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. SNL also participates in several scientific application and collaboratory pilot projects.

Stanford Linear Accelerator Center

The Stanford Linear Accelerator Center (SLAC) is located at the edge of Silicon Valley in California about halfway between San Francisco and San Jose on 426 acres of Stanford University land. The LTR subprogram at SLAC conducts research in areas such as advanced electronics, large-scale ultra-high vacuum systems, radiation physics and monitoring, polarized and high-brightness electron sources, magnet design and measurement, and controls systems through cost-shared collaborations with industry.

Thomas Jefferson National Accelerator Facility

The Thomas Jefferson National Accelerator Facility (TJNAF) is a basic research laboratory located on a 200 acre site in Newport News, Virginia. The LTR subprogram at the TJNAF conducts research in such areas as accelerator and detector engineering, superconducting radiofrequency technology, speed data acquisition, and liquid helium cryogenics through cost-shared collaborations with industry.

All Other Sites

The ASCR program funds research at 71 colleges/universities located in 24 states supporting approximately 117 principal investigators. Also included are funds for research awaiting distribution pending completion of peer review results.

A number of enabling technology centers will be established at laboratories and/or universities. Specific site locations will be determined as a result of competitive selection. These centers will focus on specific software challenges confronting users of terascale computers.

Mathematical, Information, and Computational Sciences

Mission Supporting Goals and Objectives

The Mathematical, Information, and Computational Sciences (MICS) subprogram is responsible for carrying out the primary mission of the ASCR program: discovering and developing the advanced computing and communications tools and operating the high performance computing and network facilities that researchers need to analyze, model, simulate, and — most importantly — predict complex phenomena of importance to the Office of Science and to the Department of Energy. The MICS subprogram supports fundamental research and research facilities in all of the areas in which MICS supports research:

- **Applied Mathematics.** This includes research on the underlying mathematical understanding and numerical algorithms to enable effective description and prediction of physical systems such as fluids, magnetized plasmas, or protein molecules. This includes, for example, methods for solving large systems of partial differential equations on parallel computers, techniques for choosing optimal values for parameters in large systems with hundreds to hundreds of thousands of parameters, improving our understanding of fluid turbulence, and developing techniques for reliably estimating the errors in simulations of complex physical phenomena.
- **Computer Science.** This includes research in computer science to enable large scientific applications through advances in massively parallel computing such as very lightweight operating systems for parallel computers, distributed computing such as development of the Parallel Virtual Machine (PVM) software package which has become an industry standard, and large scale data management and visualization. The development of new computer and computational science techniques will allow scientists to use the most advanced computers without being overwhelmed by the complexity of rewriting their codes every 18 months.
- **Networking.** This includes research in high performance networks and information surety required to support high performance applications – protocols for high performance networks, methods for measuring the performance of high performance networks, and software to enable high speed connections between high performance computers and networks. The development of high speed communications and collaboration technologies will allow scientists to view, compare, and integrate data from multiple sources remotely.

MICS also operates supercomputer and network facilities that are available to researchers 24 hours a day, 365 days a year. The requirements far exceed the current state-of-the-art; furthermore, the requirements far exceed the tools that the commercial marketplace will deliver. For this reason, the MICS subprogram must not only support basic research in the areas listed above, but also the development of the results from this basic research into software usable by scientists in other disciplines; and partnerships with users to test the usefulness of the research. These partnerships with the scientific disciplines are critical because they test the usefulness of current advanced computing research, enable MICS to transfer the results of this research to scientists in the disciplines, and help define promising areas for future research. This integrated approach is critical for MICS to succeed in providing the extraordinary computational and communications tools that DOE's civilian programs need to carry out their missions.

Performance Measures

- Facilities, including the National Energy Research Scientific Computing Center (NERSC) and ESnet, will be operated within budget and successfully meet user needs and satisfy overall SC program requirements where, specifically, NERSC will deliver 3.6 Teraflop capability by the end of FY 2001 to support DOE's science mission.
- Conduct regular peer review and merit evaluation based on the principles set down in 10 CFR Part 605 for grants and cooperative agreements, with all research projects reviewed at least once and no project extending more than four years without review.
- Support the Computational Science Graduate Fellowship Program with the successful appointment of 10 new students to support the next generation of leaders in computational science for DOE and the Nation.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Mathematical, Computational, and Computer Sciences Research	48,896	46,086	73,030	+26,944	+58.5%
Advanced Computation, Communications Research and Associated Activities	86,468	69,996	92,441	+22,445	+32.1%
SBIR/STTR	0[a]	2,989	4,211	+1,222	+40.9%
Total, Mathematical, Information, and Computational Sciences	135,364	119,071	169,682	+50,611	+42.5%

[a] Excludes $3,274,000 which has been transferred to the SBIR program and $196,000 which has been transferred to the STTR program.

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Mathematical, Computational, and Computer Sciences Research			

- **Applied Mathematics:** Research on the underlying mathematical understanding and numerical algorithms to enable effective description and prediction of physical systems. Research in applied mathematics is critical to the DOE because of the potential of improved mathematical techniques to enable large computational simulations. In fact, the contribution of improved mathematical methods to advancing computer simulation exceeds the contribution due to speedup in the underlying hardware. This activity supports research at DOE laboratories, universities, and private companies. Many of the projects supported by this activity are partnerships between researchers at universities and DOE laboratories. To accomplish its goals, the program supports research in a number of areas including: Mathematical Physics including string theory, superstring theory, geometry of space-time, and quantum effects; Ordinary and Partial Differential Equations including numerical methods, high performance algorithms, massively parallel algorithms, novel gridding schemes, numerical linear algebra, iterative methods, sparse solvers, and dense solvers; Control Theory including differential-algebraic systems, order reduction, queuing theory; Shock Wave Theory systems, multipole expansions, mixed elliptic-hyperbolic problems, including hyperbolic and wavelet transforms; Fluid Dynamics including compressible, incompressible and reacting flows, turbulence modeling, and multiphase flows; Dynamical Systems including chaos-theory and control, and bifurcation theory; Programming and Optimization including linear and nonlinear programming, interior-point methods, and discrete and integer programming; and Geometric and Symbolic Computing including minimal surfaces and automated theorem proving. The FY 2001 budget includes the continuation of work initiated in FY 1999 to develop the mathematical basis for modeling and simulating complex stochastic phenomena of the type that arise in vital DOE areas such as global climate modeling,

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
and environmental remediation. This research also provides the basis for Defense Programs' investments in understanding the predictability of stockpile stewardship simulation. The FY 2001 budget also includes an increased level of funding for the Computational Sciences Graduate Fellowship program ($2,000,000) and funds for the competitive selection (based on a solicitation notice to labs and universities) of two enabling technology centers focused on algorithms and mathematical libraries for critical DOE applications on terascale computers ($7,700,000)...	22,564	23,354	33,054
▪ **Computer Science:** Research in computer science to enable large scientific applications. This activity is critical to DOE because its requirements for high performance computing significantly exceed the capabilities of computer vendors' standard products. Therefore, much of the computer science to support this scale of computation must be developed by DOE. This activity supports research in two general areas: the underlying software to enable applications to make effective use of computers with hundreds or thousands of processors as well as computers that are located at different sites; and large scale data management and visualization. The first area includes research in protocols and tools for interprocessor communication and parallel input/output (I/O) as well as tools to monitor the performance of scientific applications and advanced techniques for visualizing very large scale scientific data. This research is carried out by researchers at DOE laboratories and universities, often working together in partnerships. The enhancements to this activity in FY 2001 will permit the establishment of a small number of competitively selected enabling technology centers to address critical computer science and systems software issues for terascale computers including: scalable open source operating systems; tools for analyzing and debugging scientific simulation software that uses thousands of processors; and the development of data management and visualization software capable of handling terabyte scale data sets extracted from petabyte scale data archives. ($7,476,000) These enabling technology centers are a critical component in DOE's strategy for taking the next steps in scientific simulation and modeling.	14,000	14,000	21,476

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
■ **Advanced Computing Software Tools:** This research uses the results of fundamental research in applied mathematics and computer science to develop an integrated set of software tools that scientists in various disciplines can use to develop high performance applications (such as simulating the behavior of materials). These tools, which provide improved performance on high-end systems, are critical to the ability of scientists to attack the complex scientific and engineering problems that can only be solved with high-end computing systems. The initial goal of this program element was to develop foundational tools (math libraries, runtime systems, etc.) that will have a useful life spanning many generations of computer hardware. From the experience gained with end user application scientists applying these tools, it has become clear that to promote wide usage across the scientific community the tools must also be robust and easy to use. Since many of the tools needed in the high performance arena have no commercial market, enabling technology centers will provide a means for focused investment to deploy these tools to the scientific community. These competitively selected centers will focus research in several areas that include software frameworks, problem solving environments, distributed computing and collaboration technologies, as well as visualization and data management. A substantial increase in this effort is provided to support this goal.	5,000	5,000	9,000
■ **Scientific Applications Pilot Projects:** This research applies computational techniques and tools developed in the Advanced Computing Software Tools effort to basic research problems in order to test the usefulness of current advanced computing research, transfer the results of this research to the scientific disciplines, and help define promising areas for future research. In FY 2000, Grand Challenge projects initiated in FY 1991 as part of DOE's component of the Federal High Performance Computing and Communications program were phased out. The FY 2001 funding for this activity will allow the initiation of a small number of new			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
pilot projects. The selection of these projects will be based on open, competitive processes. These pilot projects will be tightly coupled to the enabling technology centers (described above in computer science) and advanced computing software tools to ensure that these activities are an integrated approach to the challenges of terascale simulation and modeling that DOE faces to accomplish its missions.	7,332	3,732	9,500
Total Mathematical, Computational, and Computer Sciences Research..	48,896	46,086	73,030
Advanced Computation, Communications Research, and Associated Activities			
■ **Networking:** Research in high performance computer networks and information security required to support high performance computer applications — protocols for high performance networks, methods for measuring the performance of high performance networks, and software to enable high speed connections between high performance computers and both local area and wide area networks. In addition, this activity supports research in network protocols that enable applications to request, and be guaranteed, minimum acceptable levels of network capability. The enhanced level of effort in this activity in FY 2001 will enable research in the high performance "middleware," software that applications need to couple effectively to advanced network services..	4,500	6,000	7,500
■ **Collaboratory Tools:** This research uses the results of fundamental research on computer science and networking to develop an integrated set of software tools to enable scientists to remotely access and control facilities and share data in real time. These tools are necessary to provide a new way of organizing and performing scientific work that offers the potential for increased productivity and efficiency. This research includes, for example, developing and demonstrating an open, scalable approach to application level security in widely distributed, open network environments that can be used by all the collaboratory tools as well as by the advanced computing software tools whenever access control and authentication are issues. Having demonstrated feasibility of the security architecture on a small scale, an additional investment is needed to support the integration of			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
collaboratory tools with advanced networking services in a research setting. In this way, security features can be integrated into more end user applications or collaboratory tools. In addition, all these can be demonstrated on a large user base. Other examples of research in collaboratory tools include the development of a modular electronic notebook prototype for the sharing of scientific results, data from scientific instruments and design of scientific procedures; and the development of tools to manage distributed collaborations where videoconferencing, whiteboards and other shared applications are important. Shared controls for remote, collaborative control of visualizations are also being investigated.	3,000	3,000	5,600

- **National Collaboratory Pilot Projects:** R&D to test, validate, and apply collaboratory tools in partnership with other DOE programs. It is important to demonstrate and test the benefits of collaboratory tools technology in order to promote its widespread use. The two continuing pilot projects are: (1) the Materials MicroCharacterization Collaboratory, a partnership with the Basic Energy Sciences program and Energy Efficiency and Renewable Energy to provide remote access to facilities located at Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, Argonne National Laboratory, and the National Institute of Standards and Technology, and the University of Illinois for electron beam microcharacterization of materials; and (2) the Diesel Combustion Collaboratory, a partnership with Basic Energy Sciences, Energy Efficiency and Renewable Energy, and three U.S. manufacturers of diesel engines, to link researchers at Sandia National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and the University of Wisconsin with researchers at industrial laboratories in Indiana and Michigan to develop the next generation of clean diesel engines. As communications technologies and middleware developments converge and lead to new services, a closer coupling needs to be made to the end scientific applications. Hence an increase is made for R&D to test, validate, and apply wide area data intensive collaborative computing technologies in partnerships between end user application scientists, developers of collaboration tools and other middleware, and network researchers. These

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
partnerships will be focused to develop user environments where collaboration is ubiquitous and distributed computing is seamless and transparent for DOE mission applications such as High Energy and Nuclear Physics Data, remote visualization of simulation results, and advanced collaboratories.	3,000	5,000	11,000
■ **National Energy Research Scientific Computing Center (NERSC):** NERSC, located at LBNL, provides high performance computing for investigators supported by the Office of Science. The Center serves 2,000 users working on about 700 projects; 35 percent of users are university based, 60 percent are in National Laboratories, and 5 percent are in industry. NERSC provides a spectrum of supercomputers offering a range of high performance computing resources and associated software support. The two major computational resources at NERSC are a 512 processor Cray T3E computer and a large IBM SP computer whose initial installation was completed in early FY 2000 in a fully competitive procurement. The additional funding in FY 2001 will enable this computer to be enhanced to over 5 teraflops peak performance. This represents nearly a 40% increase over the capability that would have been attainable without the increase in funding. These computational resources will be integrated by a common high performance file storage system that facilitates interdisciplinary collaborations Related requirements for capital equipment and general plant projects (GPP) funding are also supported..	26,500	26,500	32,278
■ **Advanced Computing Research Facilities (ACRFs):** ACRFs support advanced computational hardware testbeds for scientific application pilot projects and fundamental research in applied mathematics and computer science. ACRFs are located at Los Alamos National Laboratory (Nirvana Blue partnership with the DOE Biological and Environmental Research (BER) program and Defense Programs (DP), based on SGI/Cray Technology); Argonne National Laboratory (IBM-SP); and Lawrence Berkeley National Laboratory (SGI/Cray T3E and IBM SP). Smaller evaluation efforts based on experimental clusters of Compaq-Alpha technology and Intel based processors are supported at ORNL and ANL. Because many of the issues to be investigated only appear in the computer systems at			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
significantly larger scale than the computer manufacturers' commercial design point, these facilities must procure the largest scale systems that can be afforded and develop software to manage and make them useful. In addition, the ACRFs, taken together, must have a full range of different computer architectures to enable comparison and reduce overall program risk. These all involve significant research efforts, often in partnership with the vendors to resolve issues including operating system stability and performance, system manageability and scheduling, fault tolerance and recovery, and details of the interprocessor communications network. Therefore, all of these systems are managed as research programs and not as information technology investments. Related capital equipment needs such as high speed disk storage systems, archival data storage systems and high performance visualization hardware are also supported. An additional $2,027,000 will allow for experiments with one additional computer architecture for a high-priority DOE application. The site will be determined competitively.	20,079	13,749	15,776

- **Energy Sciences Network (ESnet):** ESnet provides worldwide access to the Office of Science facilities, including: advanced light sources; neutron sources; particle accelerators; fusion reactors; spectrometers; ACRFs; and other leading-edge science instruments and facilities. ESnet provides the communications fabric that links DOE researchers to one another and forms the basis for fundamental research in networking, enabling R&D in collaboratory tools, and applications testbeds such as the national collaboratory pilot projects. To provide these facilities, ESnet management at LBNL contracts with commercial vendors for advanced communications services including Asynchronous Transfer Mode (ATM) and Wave Division Multiplexing (WDM). ESnet management provides system integration to provide a uniform interface to these services for DOE laboratories. In addition, ESnet management is responsible for the interfaces between the network fabric it provides and the worldwide Internet including the University Corporation for Advanced Internet Development (UCAID) Abilene network that provides high performance connections to many research universities. One

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
reason that ESnet, in the words of the 1998 external review committee, is able to provide the capabilities and services to its users “at significantly lower budgets than other agencies” is its management structure with strong user and site coordination committees. This management structure is built on DOE’s experience in operating large user facilities. The enhanced funding in FY 2001 will support an advanced network testbed to enable research in collaboratory tools and pilots as well as the increases in bandwidth needed to support terascale computers and the next generation of petabyte/year scale experimental facilities. Related capital equipment needs are also supported such as high speed network routers, ATM switches, and network management and testing equipment.	14,787	15,747	20,287
■ **Next Generation Internet (NGI):** This program focused on goals of the government-wide program and supported efforts to develop, test, and validate networking technologies that DOE mission-critical applications require. Core aspects of this long-standing research are supported within the MICS subprogram as they have been since the beginning of the HPCC program in FY 1991	14,602	0	0
Total, Advanced Computation, Communications Research, and Associated Activities	86,468	69,996	92,441

SBIR/STTR

■ In FY 1999, $3,274,000 and $196,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	2,989	4,211
Total, Mathematical, Information, and Computational Sciences	135,364	119,071	169,682

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Mathematical, Computational, and Computer Sciences Research	
■ Increase in the Computational Sciences Graduate Fellowship program and funds for the competitive selection of two enabling technology centers focused on algorithms and mathematical libraries for critical DOE applications on terascale computers.	+9,700
■ Increase in computer science for enabling technology centers - a critical component in DOE's strategy for taking the next steps in computational modeling and simulation.	+7,476
■ Increase in advanced computing software tools for enabling technology centers, for a focused investment to deploy tools to the scientific community.	+4,000
■ Increase in scientific applications pilot projects to allow the initiation of several new pilot projects that will be tightly coupled to the enabling technology centers in applied mathematics and computer science.	+5,768
Total Mathematical, Computational, and Computer Sciences Research	+26,944
Advanced Computation, Communications Research, and Associated Activities	
■ Increase in networking to enable research in the high performance "middleware" software that applications need to couple effectively to advanced network services.	+1,500
■ Increase in collaboratory tools to support the integration of collaboratory tools with advanced networking services in a research setting.	+2,600
■ Increase in national collaboratory pilot projects to test, validate, and apply collaboratory tools in partnership with other DOE programs.	+6,000
■ Increase in NERSC funding for computer enhancement.	+5,778
■ Increase in support for Advanced Computing Research Facilities (ACRFs)	+2,027
■ Increase in support of ESnet operations for an advanced network testbed and access to multi-teraflop computers.	+4,540
Total, Advanced Computation, Communications Research, and Associated Activities	+22,445
SBIR/STTR	
■ Increase in SBIR/STTR due to increase in operating expenses.	+1,222
Total Funding Change, Mathematical, Information, and Computational Sciences	+50,611

Laboratory Technology Research

Mission Supporting Goals and Objectives

The mission of the Laboratory Technology Research (LTR) subprogram is to support high risk, energy related research that advances science and technology to enable applications that could significantly impact the Nation's energy economy. LTR fosters the production of research results motivated by a practical energy payoff through cost-shared collaborations between the Office of Science (SC) laboratories and industry.

An important component of the Department's strategic goals is to ensure that the United States maintains its leadership in science and technology. LTR is the lead program in the Office of Science for leveraging science and technology to advance understanding and to promote our country's economic competitiveness through cost-shared partnerships with the private sector.

The National Laboratories under the stewardship of the Office of Science conduct research in a variety of scientific and technical fields and operate unique scientific facilities. Viewed as a system, these ten laboratories — Ames Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Princeton Plasma Physics Laboratory, Stanford Linear Accelerator Center, and Thomas Jefferson National Accelerator Facility — offer a comprehensive resource for research collaborations. The major component of the LTR research portfolio consists of investments at these laboratories to conduct research that benefits all major stakeholders — the DOE, the industrial collaborators, and the Nation. These investments are further leveraged by the participation of an industry partner, using Cooperative Research and Development Agreements (CRADAs). Another LTR program component provides rapid access by small business to the research capabilities at the SC laboratories through agile partnership mechanisms including personnel exchanges and technical consultations with small business. The LTR subprogram currently emphasizes three critical areas of DOE mission-related research: advanced materials processing and utilization, intelligent processes and controls, and energy-related applications of biotechnology.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Laboratory Technology Research	12,753	8,578	11,963	+3,385	+39.5%
SBIR/STTR	0[a]	234	325	+91	+38.9%
Congressional Direction	2,968	0	0	0	0.0%
Total, Laboratory Technology Research	15,721	8,812	12,288	+3,476	+39.4%

[a] Excludes $399,000 which has been transferred to the SBIR program and $24,000 which has been transferred to the STTR program.

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Laboratory Technology Research			
■ This activity supports research to advance the fundamental science at the Office of Science laboratories toward innovative energy applications. Through CRADAs, the SC laboratories enter into cost-shared research partnerships with industry, typically for a period of three years, to explore energy applications of research advances in areas of mission relevance to both parties. The research portfolio consists of approximately 70 projects and emphasizes the following topics: advanced materials processing and utilization, intelligent processes and controls, and energy-related applications of biotechnology. Efforts underway include the exploration of (1) a unique direct casting technology for production of lower-cost, better-performing titanium wire for use in the aerospace and automotive industries; (2) the identification of plants that can be used in freshwater, aquatic, and edge environments to remove contaminants from sediment, without substantial alteration of the ecosystems; and (3) the characterization of polymer composite matrix materials, using electron beam curing, to produce stronger, lighter, and more durable materials with much lower energy demands. A small but important component of this activity provides industry, particularly small businesses, with rapid access to the unique research capabilities and resources at the SC laboratories. These research efforts are usually supported for a few months to quantify the energy benefit of a specific problem posed by industry. Recent projects supported the development of (1) web-based energy performance benchmarking to improve the energy efficiency of buildings; (2) a magnetic particle process to separate selectively iron and chromium from plating tank solutions, thereby improving plating efficiency and minimizing waste disposal cost; and (3) tools for the genetic manipulation of *Streptococcus pneumoniae* to demonstrate gene function and to identify novel genetic elements in transcription, which could lead to improved antibiotics for respiratory disease.	12,753	8,578	11,963

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
SBIR/STTR			
In FY 1999, $399,000 and $24,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.........................	0	234	325
Congressional Direction			
Funds the University of Southwestern Louisiana (per FY 1997 Congressional Direction)...	2,968	0	0
Total, Laboratory Technology Research....................................	15,721	8,812	12,288

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Laboratory Technology Research	
■ Increase in multiyear technology research partnership projects....................	+3,385
SBIR/STTR	
■ Increase in SBIR/STTR due to increase in operating expenses.	+91
Total Funding Change, Laboratory Technology Research	+3,476

Advanced Energy Projects

Mission Supporting Goals and Objectives

The Advanced Energy Projects (AEP) subprogram funded research that established the feasibility of novel, energy-related concepts that span the Department's energy mission and goals. Funded projects were based on innovative ideas that spanned multiple scientific and technical disciplines and did not fit into any other DOE program area. A common theme for each project was the initial linkage of new research results to an energy application with a potentially significant payoff. Typically, AEP supported projects up to a level of about $250,000 per year for a period of about 3 years. Projects were selected from proposals submitted by universities and national laboratories. Funding criteria emphasized scientific merit as judged by external peer review.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Advanced Energy Projects	2,427	0	0	0	0.0%
SBIR/STTR	0[a]	0	0	0	0.0%
Total, Advanced Energy Projects	2,427	0	0	0	0.0%

Detailed Program Justification

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
Advanced Energy Projects			
■ Support for high-risk, high-payoff research at universities and national laboratories established the feasibility of novel energy related concepts that were at an early stage of scientific definition. Final funds for these projects were provided in FY 1999	2,427	0	0
SBIR/STTR			
■ In FY 1999, $62,000 and $4,000 were transferred to the SBIR and STTR programs, respectively.	0	0	0
Total, Advanced Energy Projects	2,427	0	0

[a] Excludes $62,000 which has been transferred to the SBIR program and $4,000 which has been transferred to the STTR program.

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Advanced Energy Projects	
■ The AEP program was terminated in FY 2000.	0
Total Funding Change, Advanced Energy Projects	0

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
General Plant Projects.......................	70	0	2,000	+2,000	+100.0%
Capital Equipment (total)...................	8,798	6,275	8,775	+2,500	+39.8%
Total, Capital Operating Expenses......	8,868	6,275	10,775	+4,500	+71.7%

Major Items of Equipment (TEC $2 million or greater)

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1999	FY 2000	FY 2001	Accept-ance Date
Archival Systems Upgrade – LBNL.........	2,000	0	0	2,000	0	FY 2002
Distributed Visualization Server – LBNL ..	2,500	0	0	0	2,500	FY 2001
Total, Major Items of Equipment		0	0	2,000	2,500	

Multiprogram Energy Laboratories - Facilities Support

Program Mission

The Multiprogram Energy Laboratories - Facilities Support (MEL-FS) program provides line item construction funding (i.e., projects with a total estimated cost of $5,000,000 or above) for general purpose facilities to support the infrastructure of the five Office of Science multiprogram national laboratories. These are: Argonne National Laboratory - East (ANL-E), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL). These laboratories are government-owned, contractor-operated (GOCO) and have over 1,100 buildings with 14.3 million gross square feet of space and an estimated replacement value of over $9,000,000,000. Total operating funding for these laboratories is over $3,000,000,000 a year. The Office of Science manages this program to provide a comprehensive, prioritized and equitable approach to its stewardship responsibility for the general purpose support infrastructure of these laboratories.

The program provides Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation. Local communities around ANL-E, BNL, and ORNL qualify for PILT.

The program also supports costs incurred for centralized Oak Ridge Operations Office (ORO) infrastructure requirements and general operating costs essential to maintaining a viable, functioning operations office. Activities include roads and grounds maintenance, infrastructure maintenance, physical security, emergency management, support of the Oak Ridge Financial Service Center and other technical needs related to landlord responsibilities of the ORO.

Program Goals

- To ensure that the support facilities at the multiprogram laboratories meet the Department's research needs in a safe, environmentally sound, and cost-effective manner primarily by refurbishing or replacing deteriorated, outmoded, unsafe, and inefficient general purpose infrastructure.
- To provide landlord support for the centralized Oak Ridge Operations Office and the Oak Ridge Reservation activities.

Program Objectives

- To correct Environment, Safety and Health (ES&H) inadequacies.
- To reduce risk of operational interruptions due to failed support systems.
- To provide cost effective operations and reduce maintenance costs.

- To provide quality space for multiprogram research and support activities.
- To preserve the government investment in the physical plant of the multiprogram laboratories.
- To promote performance-based infrastructure management.
- To support local communities via Payments in Lieu of Taxes (PILT).
- To provide landlord support for the Oak Ridge Reservation and for the Oak Ridge Operations Office.

Performance Measures

Performance measures related to the MEL-FS program are continuously being refined to ensure that they: 1) incorporate external/internal customer inputs; 2) drive performance; 3) address the strategic plan; and 4) focus on the effectiveness of the laboratory system. Current performance measures include:

- Support of line item construction funding to reduce risk, ensure continuity of operations, avoid or reduce costs and increase productivity. Fund highest priority needs based on scoring from Life Cycle Asset Management (LCAM) Cost-Risk-Impact Matrix.
- Overall condition of laboratory buildings. Increase the percentage of buildings rated adequate.
- Excellence in project management. Increase the percentage of projects completed within baseline cost and schedule.
- Continuity of Operations at the Oak Ridge Reservation and the Oak Ridge Operations Office. Interruptions due to infrastructure, security or emergency management system failures are minimized.
- Support of local communities. Meet, in a timely manner, DOE's obligations to local communities via Payments in Lieu of Taxes (PILT), where applicable.

Significant Accomplishments and Program Shifts

- Progress in Line Item Projects - Four projects are scheduled for construction completion in FY 2001: the Central Supply Facility at ANL-E; the Electrical Systems Modifications - Phase I at BNL; Building 77 Rehabilitation at LBNL; and the Electrical Systems Upgrade, Phase III at ANL-E.
- The program includes funding of Oak Ridge Operations Office Site Landlord activities beginning in FY 2000.
- The direct funding for the American Museum for Science and Energy (AMSE) under the Oak Ridge Landlord activities will end in FY 2000. Museum operation is transferred to Oak Ridge National Laboratory where alternative funding mechanisms are being developed, including support by private or industrial partners, and possibly, an admission fee for adults.

Funding Profile

(dollars in thousands)

	FY 1999 Current Appropriation	FY 2000 Original Appropriation	FY 2000 Adjustments	FY 2000 Current Appropriation	FY 2001 Request
Multiprogram Energy Laboratories-Facilities Support					
Multiprogram Energy Laboratories-Facilities Support	21,260	21,260	-5	21,255	23,219
Oak Ridge Landlord	0	11,800	0	11,800	10,711
Subtotal, Multiprogram Energy Laboratories-Facilities Support	21,260	33,060	-5	33,055	33,930
Use of Prior Year Balances	-13 [a]	0	0	0	0
General Reduction	0	-5	+5	0	0
Total, Multiprogram Energy Laboratories-Facilities Support	21,247	33,055	0	33,055	33,930

Public Law Authorization:
Public Law 95-91, “Department of Energy Organization Act”
Public Law 103-62, “Government Performance Results Act of 1993”

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

Funding by Site

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Chicago Operations Office					
Argonne National Laboratory	7,089	4,980	6,660	+1,680	+33.7%
Brookhaven National Laboratory	1,349	6,881	6,659	-222	-3.2%
Chicago Operations Office	1,160	1,160	1,160	0	0.0%
Total, Chicago Operations Office	9,598	13,021	14,479	+1,458	+11.2%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	4,854	6,133	2,113	-4,020	-65.5%
Oak Ridge Operations Office					
Oak Ridge National Laboratory	6,808	1,101	6,627	+5,526	+501.9%
Oak Ridge Operations Office	0	11,800	10,711	-1,089	-9.2%
Total, Oak Ridge Operations Office	6,808	12,901	17,338	+4,437	+34.4%
Washington Headquarters	0	1,000	0	-1,000	-100.0%
Subtotal, Multiprogram Energy Laboratories - Facilities Support	21,260	33,055	33,930	+875	+2.6%
Use of Prior Year Balances	-13 [a]	0	0	0	0.0%
Total, Multiprogram Energy Laboratories - Facilities Support	21,247	33,055	33,930	+875	+2.6%

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

Site Description

Argonne National Laboratory - East

Argonne National Laboratory - East (ANL-E) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. The laboratory consists of 122 facilities, 4.6 million gross square feet of space, with the average age of the facilities being 31 years. Approximately 29 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes funding the following projects:

- MEL-001-06 - Central Supply Facility (TEC $5,900,000) - This project will consolidate operations currently dispersed throughout the site into one central location.
- MEL-001-09 - Fire Safety Improvements, Phase IV (TEC $8,430,000) This project will bring 30 major facilities into compliance with the Life Safety Code and the National Fire Alarm Code.

The program also provides funding through the Chicago Operations Office for Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation.

Brookhaven National Laboratory

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The laboratory consists of 349 facilities, 4.1 million gross square feet of space, with the average age of the facilities being 39 years. Approximately 27 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding:

- MEL-001-04 - Electrical Systems Modifications, Phase I (TEC $5,730,000) This project will include: the replacement of and installation of new cables and underground ductbanks; the installation of a new 13.8 kV - 2.4 kV step-down transformer substation and replacement of other obsolete components.
- MEL-001-07 - Sanitary System Modifications, Phase III (TEC $6,500,000) This project will: replace or rehabilitate approximately 9,900 feet of existing deteriorated (8 to 20 inch) sewer piping; replace the sewage digester; connect five facilities to the sanitary system; and make other modifications to reduce discharges to the environment.
- MEL-001-13 Groundwater and Surface Water Protection (TEC $6,050,000) This proposed new start for FY 2001 will implement a backlog of ground and surface water protection projects which are commitments to regulators. These include: proper closure of inactive supply and injection wells; runoff control for the surplus material storage yard; containment and runoff control for the radioactive material storage yard; replacement of 12 hydraulic elevator cylinders; removal of 22 underground fuel oil tanks; replacement of radioactive waste tanks with secondarily contained tanks.

- MEL-001-16 Electrical Systems Modifications, II (TEC $6,770,000) This proposed new start for FY 2001 will be the second phase of the modernization and refurbishment of the laboratory's deteriorating 50 year-old electrical infrastructure. The project includes: installation of two new 13.8 kV feeders to provide alternate sources to existing, aged feeders; installation of additional underground ductbanks to support a new 13.8 kV feeder; replacement of 2.4 kV switchgear to increase system reliability and safety; reconditioning of 50 480-volt circuit breakers including replacing obsolete trip units with modern, solid-state trip devices; and the retrofit of 10 13.8 kV air breakers with new vacuum technology.

The program also provides funding through the Chicago Operations Office for Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located in Berkeley, California. The laboratory is on a 200 acre site adjacent to the Berkeley campus branch of the University of California. The laboratory consists of 118 facilities, 1.6 million gross square feet of space, with the average age of the facilities being 34 years. Approximately 19 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes to fund the following projects:

- MEL-001-05 - Building 77-Rehabilitation of Building Structure and Systems (TEC $8,000,000) This project will correct seismic deficiencies and refurbish and upgrade the electrical and mechanical systems to facilitate the high precision processes currently being performed in the facility.

- MEL-001-12 - Site-wide Water Distribution System Upgrade (TEC $8,300,000) This proposed new start for FY 2001 will rehabilitate the Lab's High Pressure Water (HPW) System to include: replacement of all 1.4 km of cast iron pipe with ductile iron pipe; installing cathodic protection; replacing and adding pressure reducing stations to prevent excessive system pressure at lower lab elevations; adding an emergency fire water tank to serve the East Canyon; and providing the two current emergency fire water tanks with new liners and seismic upgrades.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The laboratory consists of 466 facilities, 3.4 million gross square feet of space, with the average age of the facilities being 37 years. Approximately 18 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes to fund the following projects:

- MEL-001-08 Electrical Systems Upgrade (TEC $5,900,000) This project will include: replacing overhead feeders; installing advanced protective relaying capabilities at major substations; and replacing major switchgear and transformers.

- MEL-001-14 Fire Protection System Upgrade (TEC $5,920,000) This proposed new start for FY 2001 will: replace deteriorated, obsolete systems with more reliable fire alarm and suppression capabilities; replace the single 16-inch water main in the east central section of ORNL with a looped system; and extend coverage of automatic alarm systems and sprinkler systems to areas not previously served. The fire alarm receiving equipment at the site fire department headquarters will also be upgraded to ensure its reliability, modernize its technology, and meet the demands of an expanded fire alarm system network.

- MEL-001-15 Facilities HVAC Upgrade (TEC $7,100,000) This proposed new start for FY 2001 will provide improvements to aging HVAC systems (average age 38 years) located in the thirteen buildings which comprise ORNL's central research complex and additions and improvements to the chilled water distribution system. This includes: redesign of the cooling water distribution system to reduce the number of pumps required and installing more efficient pumps, thereby reducing operations and maintenance costs; installation of an 800 ft., 8-inch-diameter pipe, chill water cross-tie to Bldgs. 4501/4505 from the underground tie-line between Bldgs. 4500N/4509 to address low capacity problems in 4501/4505; installation of a 500 ft. 4-inch-diameter pipe to feed new chilled water coils in the east wing of Bldg. 3500; upgrade of the existing 50 year-old air handler with new dampers, filters, steam coils, and controls; and replacement of constant volume, obsolete air handlers in various buildings with variable air volume (VAV) improvements to more efficiently control temperature.

Oak Ridge Operations Office

The Oak Ridge Landlord program provides for centralized Oak Ridge Operations Office (ORO) infrastructure requirements and general operating costs for activities on the Oak Ridge Reservation outside plant fences and activities to maintain a viable operations office, including maintenance of roads and grounds and other infrastructure, operation of the Emergency Management Program Office, Payments In Lieu of Taxes, physical security and support for the Oak Ridge Financial Service Center as well as other technical needs related to landlord activities.

Multiprogram Energy Laboratories - Facilities Support

Mission Supporting Goals and Objectives

This subprogram supports the program's goal to ensure that support facilities at the Office of Science multiprogram laboratories can meet the Department's research needs primarily by refurbishing or replacing deteriorated, outmoded, unsafe, and inefficient general purpose infrastructure. General purpose facilities are general use, service and support facilities such as administrative space, cafeterias, general office/laboratory space, utility systems, sanitary sewers, roads, etc. Less than half of the space is considered fully adequate, while the remainder needs rehabilitation or replacement/demolition. The large percentage of inadequate space reflects the age of the facilities (average age of 33 years), changing research needs that require more office space and light laboratory space, ES&H requirements and obsolete systems.

Capital investment requirements are identified in laboratory Institutional Plans that address needs through the year 2004 based on expected programmatic support. The projected needs through the period total over $450,000,000. Of this amount, 65 percent is to rehabilitate or replace buildings; 21 percent is for utility projects; and 11 percent for ES&H projects. All projects are first ranked using a prioritization model that takes into account risk, impacts, and mission need. The projects that have ES&H as the principal driver are further prioritized using the Risk Prioritization Model from the DOE ES&H and Infrastructure Management Plan process.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
General Purpose Facilities	10,271	14,495	8,816	-5,679	-39.2%
Environment, Safety and Health	9,829	4,600	13,243	+8,643	+187.9%
Infrastructure Support	1,160	2,160	1,160	-1,000	-46.3%
Total, Multiprogram Energy Laboratories-Facilities Support	21,260	21,255	23,219	+1,964	+9.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
General Purpose Facilities			
■ Provides funding to support the initiation of one new subproject in FY 2001 as well as the continuation of one FY 2000 subproject and the completion of three FY 1999 subprojects under the Multiprogram Energy Laboratories Infrastructure Project (MEL-001). The FY 2001 funding for a new start is for design activities for the Facilities HVAC Upgrade at ORNL ($500,000). The FY 2000 subproject is the Electrical Systems Upgrade at ORNL ($5,543,000). The FY 1999 subprojects are the Central Supply Facility at ANL-E ($660,000); the Electrical Systems Modifications, Phase I at BNL ($1,000,000), and the Rehabilitation of Building 77 at LBNL ($1,113,000)..	10,271	14,495	8,816
Environment, Safety and Health			
■ Provides funding to support the initiation of four new ES&H subprojects in FY 2001, as well as the continuation of one FY 2000 subproject under the Multiprogram Energy Laboratories Infrastructure Project (MEL-001). The FY 2001 funding for new starts is for design activities for Ground and Surface Water Protection Upgrades at BNL ($1,889,000); Fire Protection System Upgrades at ORNL ($584,000); Site-wide Water Distribution System Upgrade at LBNL ($1,000,000); and Electrical Systems Modifications, II at BNL ($770,000). The FY 2000 subproject is the Fire Safety Improvements, Phase IV at ANL-E ($6,000,000). Also supports the completion of the Sanitary System Modifications, Phase III at BNL ($3,000,000).	9,829	4,600	13,243
Infrastructure Support			
■ Continue meeting Payments in Lieu of Taxes (PILT) assistance requirements for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory-East....	1,160	2,160	1,160

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Total, Multiprogram Energy Laboratories - Facilities Support	21,260	21,255	23,219

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
■ The increase from FY 2000 to FY 2001 for the General Purpose Facilities and the Environment, Safety and Health programs reflects the additional new project starts in FY 2001..	+2,964
■ The decrease in the Infrastructure Support subprogram is for Payments in Lieu of Taxes (PILT) which were increased by $1,000,000 in the FY 2000 appropriation to eliminate arrearages through fiscal year 1998...	-1,000
Total Funding Change, Multiprogram Energy Laboratories - Facilities Support...............	+1,964

Oak Ridge Landlord

Mission Supporting Goals and Objectives

This subprogram supports landlord responsibilities for the centralized Oak Ridge Operations Office including infrastructure of the Oak Ridge Reservation (the 24,000 acres of the Reservation outside of the Y-12 plant, ORNL, and the East Tennessee Technology Park). This includes roads and grounds maintenance, infrastructure maintenance, support of the Oak Ridge Financial Service Center, physical security, emergency management, PILT for Oak Ridge communities, and other technical needs related to landlord requirements.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Oak Ridge Landlord	0	11,800	10,711	-1,089	-9.2%

Detailed Program Justification

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
Oak Ridge Landlord			
■ Roads, Grounds and Other Infrastructure and ES&H Improvements.	0	2,200	2,200
■ Physical Security for the Oak Ridge Operations Office landlord responsibilities - provides for an around the clock security force.	0	2,500	2,500
■ Emergency Management Program Office - provides for the operation of the Oak Ridge Emergency Operations Center and the Communications and Operations Center.	0	1,400	1,400
■ Payments in Lieu of Taxes (PILT) to the City of Oak Ridge, and Anderson and Roane Counties	0	1,700	1,700
■ American Museum of Science and Energy – supports operation of the museum. Direct support for the museum ends in FY 2000. Museum operation will be transferred to ORNL where alternative funding mechanisms are being developed, including support by private or industrial partners, and possibly an admission fee for adults.	0	1,100	0

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
■ Oak Ridge Financial Service Center – provides computer and systems support to the Center which serves other DOE field offices as well as Oak Ridge.	0	2,000	2,000
■ Other Technical Support includes recurring activities such as computer and systems support for Directives and Training activities and one-time activities such as the identification, packaging, and shipment of documents relating to Human Radiation Experimentation to the National Archives for permanent storage and support for legacy legal cases.	0	900	911
Total, Oak Ridge Landlord	0	11,800	10,711

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Oak Ridge Landlord	
■ Direct support for the American Museum of Science and Energy will end in FY 2000. Museum operation will be transferred to Oak Ridge National Laboratory which is developing alternative funding mechanisms including support by private or industrial partners, and possibly an admission fee for adults.	-1,100
■ Continue technical support at FY 2000 level of effort	+11
Total Funding Change, Oak Ridge Landlord	-1,089

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
General Plant Projects	0	300	200	-100	-33.3%
Capital Equipment	0	100	325	+225	+225.0%
Total, Capital Operating Expenses	0	400	525	+125	+31.3%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1999	FY 2000	FY 2001	Unapprop. Balance
Project - MEL-001 Multiprogram Energy Laboratories Infrastructure Project FY 2001 Datasheet	N/A	N/A	14,924	18,351	22,059	31,427
Total, MELFS Construction [a]	N/A	N/A	20,100 [a]	19,095 [a]	22,059 [a]	31,427

[a] Total MELFS construction, including projects fiscally completed prior to FY 2001.

MEL-001 - Multiprogram Energy Laboratories, Infrastructure Project, Various Locations

(Changes from FY 2000 Congressional Budget Request are denoted with a vertical line in the left margin.)

Significant Changes

Five new starts in FY 2001 include: Ground and Surface Water Protection Upgrades at Brookhaven National Laboratory, Fire Protection System Upgrades at Oak Ridge National Laboratory; Site-wide Water Distribution System Upgrade at Lawrence Berkeley National Laboratory; Facilities HVAC Upgrade at Oak Ridge National Laboratory; and Electrical Systems Modifications, II at Brookhaven National Laboratory.

1. Construction Schedule History

Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		

N/A -- See subproject details

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Design and Construction			
FY 1998	7,259	7,259	2,358
FY 1999	14,924	14,911	9,561
FY 2000	18,351	18,351	17,789
FY 2001	22,059	22,059	22,567
FY 2002	20,150	20,150	19,564
FY 2003	11,277	11,277	14,546
FY 2004	0	0	7,185
FY 2005	0	0	437

3. Project Description, Justification and Scope

This project funds two types of subprojects:

- Projects that renovate or replace inefficient and unreliable general purpose facilities (GPF) including general use, service and support facilities such as administrative space, cafeterias, utility systems, and roads; and

- Projects to correct ES&H deficiencies including fire safety improvements, sanitary system upgrades and electrical system replacements.

General Purpose Facility Projects:

a. Subproject 01 - Upgrade Steam Plant, ORNL

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
5,300	3,400	1,900	0	0	0	1Q 1998 - 4Q 1999

This project upgraded the ORNL steam plant by adding a new steam boiler of approximately 100,000 pounds per hour capacity and capable of burning both natural gas and fuel oil. The boiler was procured with all necessary ancillary equipment, such as blowers, feedwater pumps, and controls. Suitable weather protection is provided.

This project was needed because of the age of the five existing boilers. Three are 46 years old, one is 44 years old, and the fifth is 32 years old. The new boiler capacity allows decreased firing time on the oldest boilers and extends their useful life. In addition, the new boiler improves the efficiency of the steam plant.

b. Subproject 04 - Electrical Systems Modifications, Phase I (BNL)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
5,730	0	849	3,881	1,000	0	2Q 1999 - 4Q 2001

This project is the first phase of a planned modernization and refurbishment of the Laboratory's electrical infrastructure. The project provides for the replacement of 30 to 50 year old deteriorating underground electrical cables, the addition of underground ductbanks to replace damaged portions and support new cabling, the installation of a new 13.8 kV - 2.4 kV step-down transformer substation to address capacity and operational problems, and the retrofitting/reconditioning of switchgear power circuit breakers.

c. Subproject 05 - Bldg. 77 - Rehabilitation of Building Structure and Systems (LBNL)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
8,000	0	754	6,133	1,113	0	2Q 1999 - 4Q 2001

This project will rehabilitate Building 77's structural system to restore lateral force resistance and arrest differential foundation settlement, and will modernize architectural, mechanical, and electrical systems. These upgrades will restore this 33 year-old, 68,000 sq.ft. building to acceptable seismic performance; provide environmental controls appropriate to precision fabrication processes; increase the reliability and maintainability of building systems; provide flexibility to meet future challenges; and extend building life by 40 years and building systems by 20 to 25 years.

d. Subproject 06 - Central Supply Facility (ANL-E)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
5,900	0	1,860	3,380	660	0	2Q 1999 - 4Q 2001

This project includes a 22,000 sq.ft. addition to the Transportation and Grounds Facility (Bldg. 46) along with remodeling of 3,500 sq.ft. of space in the existing Transportation and Grounds Facility. The project will result in economies and efficiencies by providing a highly efficient and cost-effective consolidated facility to meet the missions of the Materials Group and the Property Group of ANL-East and will eliminate the need for 89,630 square feet of substandard (50 year-old) space in six buildings which will be demolished (Bldgs. 4, 5, 6, 26, 27, and 28). The Materials Group receives, sorts, stores, retrieves, and distributes the majority of all materials and supplies for the Laboratory. The Property Group tags, controls, stores, and distributes excess property and precious metals for the Laboratory. This facility will contain truck docks; receiving and distribution areas; inventory control; general material storage; support and office areas; property storage; and exterior hazardous storage. This project will also eliminate 7,000 linear feet of steam supply and return lines.

e. Subproject 08 - Electrical Systems Upgrade (ORNL)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
5,900	0	0	357	5,543	0	3Q 2000 - 3Q 2002

This project will replace electrical distribution feeders and upgrade transformers and switchgear feeding research facilities and primary utility support facilities throughout the Oak Ridge National Laboratory (ORNL) complex. It will also provide advanced protective relaying and metering capabilities at major substations. The project is part of a phased infrastructure upgrade to restore the electrical distribution systems serving the ORNL. The purpose of the upgrade is to maintain a reliable source of electrical power appropriate for servicing scientific research facilities. Without the proposed upgrade, the potential for electrical faults and outages will increase as the distribution system ages, with attendant increased risk of equipment damage and the potential inability to meet laboratory programmatic goals due to downtime of critical facilities. These facilities include the central research facilities, supercomputing facility, Robotics and Process Systems facility, the central chilled water plant, and the steam plant. Also, maintenance costs involved in continued operation of the existing deteriorated system will increase as the system ages.

f. Subproject 15 – Laboratory Facilities HVAC Upgrade (ORNL)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
7,100	0	0	0	500	6,600	2Q 2001 – 1Q 2004

This project will provide improvements to aging HVAC systems (average age 38 years) located in the thirteen (13) buildings which comprise Oak Ridge National Laboratory's (ORNL's) central research complex and additions and improvements to the chiller water distribution system. This includes:
redesign of the cooling water distribution system to reduce the number of pumps required and installing more

efficient pumps, thereby reducing operations and maintenance costs; installation of an 800 ft., 8-inch-diameter pipe, chill water cross-tie to Bldgs. 4501/4505 from the underground tie-line between Bldgs. 4500N/4509 to address low capacity problems in 4501/4505; installation of a 500 ft. 4-inch-diameter pipe to feed new chilled water coils in the east wing of Bldg. 3500; upgrade of the existing 50 year-old air handler with new dampers, filters, steam coils, and controls; and replacement of constant volume, obsolete air handlers in various buildings with variable air volume (VAV) improvements to more efficiently control temperature.

<u>ES&H Projects</u>:

a. Subproject 02 - Electrical Systems Rehab. Phase IV, (LBNL)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
6,500	2,400	4,100	0	0	0	2Q 1998 - 3Q 2000

The Blackberry Switching Station Replacement Project is the last major planned rehabilitation to the LBNL electrical power system, in order to maintain its reliability and improve its safety. The project upgraded the existing 12 kV power system and utilized circuit breakers installed in the FY 1987 MEL-FS project improvement to the main Grizzly Substation.

The project corrected existing deficiencies in the power distribution system that serves the Blackberry Canyon Service Area. The improvements replaced the existing electrical system, which consisted of aged and underrated electrical equipment, 20 to 30 years old in many instances, which is difficult to maintain and unsafe to operate. It provided the Laboratory with increased operational flexibility as well as improvements in reliability, maintainability and safety.

b. Subproject 03 - Electrical Systems Upgrade, Phase III, (ANL-E)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
7,620	1,459	4,961	1,200	0	0	2Q 1998 - 1Q 2001

The project provides for the upgrade of the main electrical substation at Facility 543 and Facility 549A.

The work consists of the following items: install a new 138 kV overhead steel pole transmission line and upgrade the existing transmission line; relocate an existing transformer; upgrade existing transformers; replace existing 13.2 kV outdoor switchgear; and replace existing oil circuit breaker.

The intended project will accomplish several objectives related to system reliability, personnel safety, environmental hazards, risk reduction and system expansion.

c. Subproject 07 - Sanitary System Modifications, Phase III, (BNL)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
6,500	0	500	3,000	3,000	0	2Q 1999 - 2Q 2002

The BNL Sanitary System consists of over 20 miles of collection piping that collects sanitary waste from nearly all the BNL facilities. The collection piping transports the waste via gravity piping and lift stations to a sewage treatment plant (STP). This project is the third phase of the upgrade of the Laboratory sanitary waste system. In the first two phases, major operations of the STP were upgraded and approximately 14,000 feet of trunk sewer lines were replaced, repaired, or lined. Phase III will continue this upgrade and will replace or rehabilitate approximately 9,900 feet of existing deteriorated (8 to 20 inch) sewer piping, connect five facilities to the sanitary system by installing 7,500 feet of new sewer pipe, and two new lift stations. This will eliminate non-compliant leaching fields and cess pools, reduce non-contact cooling water flow into the sewage system by 72 million gallons per year by: diverting flow to the storm system; converting water heat exchangers to air cooled condensers; and replacing water cooled equipment in 15 buildings. The STP anaerobic sludge digester will be replaced with an aerobic sludge digester to eliminate high maintenance activity and improve performance, and install liners and modify the under drain piping in the STP sand filter beds.

d. Subproject 09 - Fire Safety Improvements, Phase IV, (ANL-E)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
8,430	0	0	400	6,000	2,030	3Q 2000 - 2Q 2003

This project will complete the effort of correcting known deficiencies with respect to fire detection and alarm systems; life safety and OSHA related sprinkler systems; and critical means of egress in twenty-eight (28) buildings at the Argonne National Laboratory-East (ANL-E) site. Correction of these deficiencies is required to comply with DOE Order 420.1, OSHA 1910,164, and OSHA Subpart C. These deficiencies, if uncorrected, could result in unmitigated risks of injury to personnel and/or damage to DOE property in case of fire.

e. Subproject 12 - Site-wide Water Distribution System Upgrade, (LBNL)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
8,300	0	0	0	1,000	7,300	2Q 2000 - 2Q 2004

This project will rehabilitate the Laboratory’s High Pressure Water (HPW) System that supplies over 100 facilities at LBNL. The HPW System provides domestic water, fire water, treated water, cooling tower water and low conductivity water. It consists of 9.6 km of pipe (1.4 km of cast iron pipe, 6.3 km of ductile iron pipe, and 1.9 km of cement lined coated steel pipe), associated valves, pumps, fittings etc. and two 200,000 gallon emergency fire water tanks. This project will: replace all cast iron pipe, which is in imminent danger of failing, with ductile iron pipe; electrically isolate pipe and provide cathodic protection; replace leaking valves and add pressure reducing stations to prevent excessive system pressure at lower lab elevations; add an emergency fire water tank to serve the East Canyon; and provide the two current emergency fire water tanks with new liners and seismic upgrades.

f. Subproject 13 - Groundwater and Surface Water Protection Upgrades, (BNL)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
6,050	0	0	0	1,889	4,161	2Q 2001 - 2Q 2004

This project will implement a backlog of ground and surface water protection projects that are commitments to regulators. These include: proper closure of inactive supply and injection wells; runoff control for the surplus material storage yard; containment and runoff control for the radioactive material storage yard; replacement of 12 hydraulic elevator cylinders; removal of 22 underground fuel oil tanks; and other Suffolk County DHS Article 12 upgrades.

g. Subproject 14 - Fire Protection System Upgrade, (ORNL)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
5,920	0	0	0	584	5,336	2Q 2001 - 2Q 2004

This project will upgrade the 36 year-old fire protection system with improved, more reliable fire alarm and suppression capabilities by: replacing deteriorated, obsolete systems; replacing the single 16-inch water main in the east central section of ORNL with a looped system (7,000 lf of 16 inch pipe); and by extending coverage of automatic alarm systems and sprinkler systems to areas not previously served. New fire alarm equipment will provide emergency responders with greatly improved annunciation of the causes and locations of alarms and will provide code compliant occupant notification evacuation alarms for enhanced life safety. It will also include timesaving, automatic diagnostic capabilities that will reduce maintenance costs. The new occupant notification systems will comply with the Americans with Disabilities Act. The fire alarm receiving equipment at the site fire department headquarters will be upgraded to ensure its reliability, modernize its technology, and meet the demands of an expanded fire alarm system network.

h. Subproject 16 – Electrical Systems Modifications II, (BNL)

TEC	Prev.	FY 1999	FY 2000	FY 2001	Outyear	Construction Start/ Completion Dates
6,770	0	0	0	770	6,000	2Q 2001 – 1Q 2003

This project is the second phase of the modernization and refurbishment of the Laboratory's deteriorating 50 year-old electrical infrastructure. The project includes: installation of two new 13.8 kV feeders to provide alternate sources to existing, aged feeders; installation of additional underground ductbanks to support a new 13.8 kV feeder; replacement of 2.4 kV switchgear to increase system reliability/safety; reconditioning of 50 480-volt circuit breakers including replacing obsolete trip units with modern, solid-state trip devices; and the retrofit of 10 13.8 kV air breakers with new vacuum technology.

4. Details of Cost Estimate

N/A

5. Method of Performance

Design will be negotiated by architect-engineer contracts or laboratory personnel. To the extent feasible, construction and procurement will be accomplished by fixed-price contracts awarded on the basis of competitive bids.

6. Schedule of Project Funding

N/A

7. Related Annual Funding Requirements

N/A

Energy Research Analyses

Program Mission

The mission of the Energy Research Analyses (ERA) program is to evaluate the quality and impact of Department of Energy research programs and projects.

Program Goal

Provide Department of Energy program managers and senior managers with objective assessments of research projects and programs in order to evaluate the quality and impact of these efforts, to identify undesirable duplications and gaps, and to provide analysis of key technical issues in support of long range energy research planning, science and technology planning, and technical and performance evaluation of departmental programs and objectives.

Program Objectives

- *To Provide The Basis For Judgments on The Quality of Research And Its Impact*. Using merit review with peer evaluation for technology and research/development programs, provide departmental program managers and their superiors with detailed information about the technical strengths and weaknesses of projects that comprise the research and development (R&D) program as a basis for judgment of the quality of the research and its impact.
- *To Provide Independent Views of Future R&D Needs in Areas of Interest to The Department*. Evaluate the status of science and technology areas of potential importance to the Department's mission, and to lay out appropriate fundamental and applied research and development to hasten the advance towards potential energy applications.
- *To Develop Strategic And Performance Plans*. Use advice from outside experts, advisory committees, departmental managers, national laboratory managers, industrial scientists and managers, and officials of other government agencies to formulate strategic and performance plans for the Office of Science and for the Science and Technology business line of the Department.
- *To Contribute to DOE And Interagency Program Analysis And Planning For Government Science And Technology*. Support participation in committees, task forces, working groups, and workshops of the Department of Energy and organizations such as the National Science and Technology Council, the National Science Foundation, the National Academy of Sciences, and private sector organizations such as the Industrial Research Institute, and the Electric Power Research Institute.

Performance Measures

- Quality and value of peer review evaluations, as indicated by satisfaction of investigators and program managers and actions taken to improve or replace projects that have significant shortcomings, and to capitalize on the strengths of stronger projects.

- Satisfaction by customer program managers with assessments of science and technology needs, as indicated by changes or additions to make DOE programs and projects more productive and relevant to DOE missions.

- Quality and acceptance of strategic and performance plans, as indicated by their use by the Director of the Office of Science and by program offices in multi-year program planning, program management, and in effectively justifying programs.

- Influence on government science and technology planning and analysis, as indicated by contributions to DOE, interagency, and outside recommendations on science policies and plans.

Significant Accomplishments and Program Shifts

- Independent peer reviews assessed the quality and relevance of over 100 DOE projects and tasks in FY 1999.

- A new Office of Science Strategic Plan was developed in FY 1999 that will be implemented in FY 2000 to guide the Office of Science into the first quarter of the next century.

- A Department of Energy Science Portfolio was developed in FY 1999 to characterize the R&D efforts within the department with regard to basic research. This portfolio will be maintained to assist the Director of the Office of Science to better manage the Department's Science investments.

Funding Profile

	(dollars in thousands)				
	FY 1999 Current Appropriation	FY 2000 Original Appropriation	FY 2000 Adjustments	FY 2000 Current Appropriation	FY 2001 Request
Energy Research Analyses					
Energy Research Analyses	976	1,000	-9	991	1,000
Subtotal, Energy Research Analyses	976	1,000	-9	991	1,000
Use of Prior Year Balances	-92[a]	0	0	0	0
General Reduction.......................	0	-4	4	0	0
Contractor Travel.........................	0	-5	5	0	0
Total, Energy Research Analyses......	884[b]	991	0	991	1,000

Public Law Authorization:
Public Law 95-91, "Department of Energy Organization Act"
Public Law 103-62, "Government Performance Results Act of 1993"

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $23,000 which has been transferred to the SBIR program and $1,000 which has been transferred to the STTR program.

Funding by Site

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Albuquerque Operations Office					
Sandia National Lab/Albuquerque	0	50	75	+25	+50.0%
Chicago Operations Office					
Brookhaven National Laboratory	48	50	0	-50	-100.0%
Fermi National Accelerator Laboratory	0	0	60	+60	+100.0%
Chicago Operations Office	231	0	0	0	0.0%
Total, Chicago Operations Office	279	50	60	+10	+20.0%
Oak Ridge Operations Office					
Oak Ridge National Laboratory	0	40	40	0	0.0%
Oak Ridge Institute for Science and Education	10	0	100	+100	+100.0%
Total, Oak Ridge Operations Office	10	40	140	+100	+250.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	165	30	75	+45	+150.0%
Richland Operations Office					
Pacific Northwest National Laboratory	250	250	300	+50	+20.0%
Washington Headquarters	272	571	350	-221	-38.7%
Subtotal, Energy Research Analyses	976	991	1,000	+9	+0.9%
Use of Prior Year Balances	-92[a]	0	0	0	0.0%
Total, Energy Research Analyses	884[b]	991	1,000	+9	+0.9%

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $23,000 which has been transferred to the SBIR program and $1,000 which has been transferred to the STTR program.

Site Description

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York.

Fermi National Accelerator Laboratory (Fermilab)

Fermilab is located on a 6,800-acre site about 35 miles west of Chicago, Illinois.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located in Berkeley, California. The Laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. This activity contributes to the Energy Research Analyses program's formulation of long-term plans and science policy.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on 150 acres in Oak Ridge, Tennessee.

Oak Ridge National Laboratory

Oak Ridge National Laboratory is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. Oak Ridge National Laboratory supports the Energy Research Analyses program in technical reviews of Department research programs. This activity includes technical support for peer review assessments and other studies and workshops as requested.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory is a Multiprogram Laboratory located on a 640 acre site at the Department's Hanford site in Richland, Washington. Pacific Northwest National Laboratory carries out research in the areas of technical planning and economic analysis to contribute to the Energy Research Analyses program's formulation of long term plans and science policy. This activity includes assessments of international basic energy science programs and private sector investments in energy R&D.

Sandia National Laboratories

Sandia National Laboratories (SNL) is a Multiprogram Laboratory, with a total of 3,700 acres, located in Albuquerque, New Mexico, with sites in Livermore, California, and Tonapah, Nevada. Sandia National Laboratory carries out research in the areas of technical program planning and merit review practices to contribute to the Energy Research Analyses program's formulation of best practices for long term plans, science policy and peer reviews. This activity includes assessments of best practices in research and development organizations.

All Other Sites

Includes funds for research awaiting distribution pending finalization of program office detailed planning.

Energy Research Analyses

Mission Supporting Goals and Objectives

The Energy Research Analyses (ERA) program assesses research projects and programs in order to judge the significance of these efforts and to identify undesirable duplications and gaps. Peer reviews of individual research projects using outside experts are performed. Technical assessments to determine the direction of future research and state-of-the-science reviews are also performed. The program also provides analyses in support of long-range energy research planning, science and technology planning, and technical evaluation of DOE programs and objectives.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Energy Research Analyses	976	965	973	+8	+0.8%
SBIR/STTR	0[a]	26	27	+1	+3.8%
Total, Energy Research Analyses.......	976	991	1,000	+9	+0.9%

Detailed Program Justification

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
Energy Research Analyses			
■ Evaluate the quality and relevance of research projects in Science, Fossil Energy, and Energy Efficiency by independent peer reviews and assess additional technical needs in Science, Fossil Energy, and Energy Efficiency (e.g., advanced composite materials). Evaluate critical planning and policy issues of DOE science and technology through reviews by expert groups outside the Department such as the National Academy of Sciences and the JASON group..	976	965	973

[a] Excludes $23,000 which has been transferred to the SBIR program and $1,000 which has been transferred to the STTR program.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
SBIR/STTR			
■ In FY 1999, $23,000 and $1,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	26	27
Total, Energy Research Analyses..	976	991	1,000

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Energy Research Analyses	
■ There are no significant funding changes from FY 2000 to FY 2001 for Energy Research Analyses..	+8
SBIR/STTR	
■ Increase in SBIR/STTR due to increase in operating expenses.	+1
Total Funding Change, Energy Research Analyses..	+9

Fusion Energy Sciences

Program Mission

The Fusion Energy Sciences program is a multi-purpose, scientific research effort, producing valuable scientific knowledge and technological benefits in the near term and providing the science base for a fusion energy option in the long term.

This is a time of important progress and scientific discovery in fusion research. By virtue of previous investments in facilities, sophisticated diagnostics, critical technologies, and modeling capabilities, the Fusion Energy Sciences program is making great progress in understanding the fundamental processes involved in confining fusion fuels, such as the turbulence responsible for loss of particles and energy across magnetic field lines. In addition, the program is exploring innovative approaches to fusion energy, including supporting advances in state-of-the-art enabling technology, in search of an optimized confinement system with an affordable development path.

Program Goal

During the next 50 years, the world population is expected to increase substantially, and energy usage will likely double. As oil and natural gas reserves are depleted, sustainable new energy sources will be needed. Both the President's Committee of Advisors on Science and Technology and the Secretary of Energy Advisory Board have recognized the potential of fusion energy and have recommended that fusion be a key component of the nation's long-term energy strategy. Accordingly, the long-range goal of the Fusion Energy Sciences program is to:

> *" Advance plasma science, fusion science, and fusion technology, and thereby establish the knowledge base for an economically and environmentally attractive fusion energy source."*

In pursuit of this goal, the program addresses a broad range of science and technology issues, resulting in spinoffs with many near-term applications.

Program Objectives

The objectives of the Fusion Energy Sciences program have been developed through extensive stakeholder meetings and were endorsed by the Fusion Energy Sciences Advisory Committee and the Secretary of Energy Advisory Board. They are summarized below.

- *Understand the science of plasmas, the fourth state of matter*. Plasmas comprise most of the observable universe, both stellar and interstellar, and have many practical applications. Progress in both plasma science and requisite supporting technology have contributed to the progress in fusion research and, conversely, fusion research has been the dominant driver of plasma science.
- *Identify and explore innovative and cost-effective development paths to fusion energy*. There are several approaches to fusion under investigation in the current program. They range from the advanced tokamak, which is the best understood magnetic confinement concept, and alternative magnetic configurations, to inertial confinement using particle beam or laser drivers.

- *Explore the science and technology of energy producing plasmas, the next frontier in fusion research, as a partner in an international effort*. Fusion research is a worldwide activity, with 80% of the research being conducted outside of the United States. International collaborations are a key strategic element of the U.S. fusion program, allowing us to leverage our funds by gaining access to facilities abroad needed to deal with scientific issues without having to use scarce resources to construct and operate them. Working from similar motivations, many scientists from abroad have participated in experiments on U.S. facilities as well. Interacting with highly qualified scientists from other countries and cultures provides an opportunity to see issues from new and different perspectives, allows solutions to arise from the diversity of the participants, and promotes both cooperation and friendly competition. In short, it provides an exciting and stimulating environment resulting in a synergistic effect that is good for science.

The Fusion Energy Sciences program is composed of three subprograms; Science, Facility Operations, and Enabling R&D. The Science subprogram includes research funds for general plasma science; for experiments on the physics of high temperature plasms in magnetic fields, in both tokamaks and other configurations; for the physics of heavy ion beam accelerators; and for theory and modeling of fusion plasmas. Funds for building, operating, upgrading and decommissioning of major facilities are in the Facility Operations subprogram. The Enabling R&D subprogram includes funds for key fusion technology research and innovations needed to advance fusion science and develop the knowledge base for an attractive fusion energy source. Many of the advances in fusion science that have occurred during the past 30 years have been enabled by technology innovations.

The Fusion Energy Sciences program today is focused primarily on the first two objectives above and the related enabling technology research. Only a small effort on burning plasma physics and related fusion technology, e.g. materials science and engineering research on energy conversion and tritium handling continues.

Scientific Facilities Utilization

The Fusion Energy Sciences request includes $95,000,000 to operate scientific user facilities. This investment will provide research time for about 500 scientists in universities, federally sponsored laboratories, and industry. It will also leverage both federally and internationally sponsored research, consistent with the Administration's strategy for enhancing the U.S. National science investment. The proposed funding will support operations at the Department's three major fusion energy physics facilities: the Doublet III-D tokamak at General Atomics, the Alcator C-Mod tokamak at the Massachusetts Institute of Technology, and the National Spherical Torus Experiment at the Princeton Plasma Physics Laboratory.

Performance Measures

The Fusion Energy Sciences program supports the Department's strategic goal of delivering the scientific and technological innovations critical to meeting the Nation's energy challenges. The performance measures of the Fusion Energy Sciences program fall into four areas: (1) excellence of the science, (2) relevance to the DOE mission and national needs, (3) stewardship of research capabilities, and (4) management of human resources. The ways in which the Fusion Energy Sciences program measures performance include merit-based peer review, charges to the Fusion Energy Sciences Advisory Committee (FESAC), and recognition of professional accomplishments of research performers. These measures have been an integral part of the program for many years. Each major research facility has a community based Program Advisory Committee (PAC) that sets priorities for the use of that facility. Proposals for new facilities or upgrades to existing facilities at laboratories receive both scientific and engineering/cost/schedule reviews.

For FY 2001, specific performance measures are:

- Initiate and meet schedules for dismantling, packaging, and offsite shipping of the Tokamak Fusion Test Reactor (TFTR) systems located in the basement of the TFTR building as described in the Decontamination and Decommissioning plan.
- Sustain partnerships that support fusion/plasma sciences, specifically through completion by June 2001 of a new NSF/DOE Partnership in Basic Plasma Science and Engineering to provide continuity after the present agreement ends, and by initiating a new element of the U.S.-Japan collaborative program by the end of FY 2001.
- Evaluate first physics results from the innovative Electric Tokamak (ET) at UCLA, where the long-range goals of this university-scale program (funded at about $2,000,000 per year) are to study fast plasma rotation and associated radial electric fields due to radiofrequency-drive, in order to enhance plasma pressure in sustained, stable plasmas.
- Improve nonlinear magneto-hydrodynamics codes to be capable of computing the effect of realistic resistive walls and plasma rotation on advanced tokamak pressure limits. (These codes may also be capable of modeling the startup of alternate configurations such as the spheromak.)
- Complete by June 2001 the 6 MW power upgrade of the DIII-D microwave system and initiate experiments with it to control and sustain plasma current profiles, with the goal of maintaining improved confinement of plasma energy for longer periods of time.
- Initiate a new phase of the U.S.-Japan collaborative program of research on enabling technologies, materials, and science for an attractive fusion energy source.
- Transfer the waste management and environmental monitoring activities at the Princeton Plasma Physics Laboratory (PPPL) from the Environmental Management program (EM) to the Fusion Energy Sciences program.
- Complete the DOE-Japan Atomic Energy Research Institute (JAERI) collaboration at the Tritium Systems Test Assembly (TSTA) facility at Los Alamos National Laboratory (LANL).

Significant Accomplishments and Program Shifts

There were six Performance Measures in the FY 1999 Fusion Energy Sciences budget narrative. Each of the six performance measures was either met or exceeded.

- The National Academy of Sciences is reviewing the quality of science in the Fusion Energy Sciences Program. An interim report was issued in August 1999, highlighting the contributions of fusion science to other fields of research. The full study, including strategic recommendations, will be completed in FY 2000.
- All three of the major fusion experiments have been operating as national facilities with research teams composed of participants from throughout the fusion science community. Program advisory committees assure scientific quality and program relevance of the research conducted at each facility.

- The National Spherical Torus Experiment (NSTX) project at the Princeton Plasma Physics Laboratory (PPPL) was completed in FY 1999, achieving its first major operational milestone ahead of schedule. A national research team was organized and the facility began experimental operations in FY 1999.
- Considerable progress has been made in areas such as the macroscopic equilibrium and stability of magnetically confined plasmas and turbulence and transport in tokamak plasmas. Software and hardware were developed that allow remote collaborations on a wide variety of fusion experiments in the United States and abroad.
- The fusion program continued exploring a wide range of confinement concepts other than the tokamak. Including the three new innovative confinement experiments that started operation in FY 1999, there are 13 exploratory level alternate magnetic concept experiments in the United States. In addition, there was increased effort on exploring the physics of a heavy ion accelerator for inertial fusion energy.
- The technology program subelement was restructured in FY 1999, and U.S. participation in the International Thermonuclear Experimental Reactor project was successfully completed.

Other significant accomplishments include:

- A major review of magnetic and inertial fusion energy options was carried out by a task force of the Secretary of Energy Advisory Board in response to congressional requests. The task force report was issued in August 1999. The report's Executive Summary states that "In the light of the promise of fusion and the risks arising from increasing worldwide energy demand and from eventually declining fossil energy supply, it is our view that we should pursue fusion aggressively." The task force also endorsed the revised focus of the magnetic fusion program to understand the science and technology of fusion and concluded that inertial fusion energy warranted continued exploration and development.
- At a two-week long workshop, 350 fusion researchers from the United States and abroad discussed virtually all of the key technical issues associated with fusion science. This workshop provided a very effective forum for enhanced interaction between magnetic fusion and inertial fusion approaches, between science and technology issues, and between basic understanding and energy applications of fusion. The community reaffirmed that the next frontier in magnetic fusion is the science of burning plasmas, and that the tokamak is technically ready for a high-gain burning plasma experiment.
- The Fusion Energy Sciences Advisory Committee (FESAC) led a community assessment of the restructured fusion program and provided a report, with specific recommendations on program priorities and balance, in September 1999.
- Preparation of a strategic plan for Fusion Energy Sciences was initiated in FY 1999. It will be completed early in 2000 incorporating the results of the Secretary of Energy Advisory Board and National Research Council reviews, the recommendations of the Fusion Energy Sciences Advisory Committee, and technical understandings that came from the 1999 Fusion Summer Study.
- DOE and NSF issued a joint announcement for new opportunities for funding in FY 2000 in September 1999 as part of the NSF/DOE Partnership in Basic Plasma Science and Engineering.

- In FY 1999, the general plasma science program was extended to include national laboratories with a solicitation for proposals on applications of plasma science. Proposals, many of which will have evolved from Laboratory Directed R&D programs, will be competitively peer reviewed.
- In late FY 1999 Los Alamos National Laboratory identified future operating cost increases for the Tritium System Test Assembly (TSTA) facility, which was built to study the fusion fuel cycle process. Following DOE and peer review, agreement was reached to complete the highly successful research program by mid-FY 2001. Research will cease then while operation to reduce the inventory of tritium fuel will continue, in preparation for transfer to EM for subsequent decontamination and decommissioning.

Science Accomplishments

During the past year, scientific accomplishments covered a wide range of activities ranging from improvements in the detailed understanding of fusion plasma confinement physics to theory and modeling advances that also contribute to fields outside of fusion science. Important examples include the following:

- *Magnetic Reconnection:* The tearing and reconnection of magnetic field lines is of fundamental importance in many areas of plasma physics, including fusion science. Newly developed laboratory experiments at the California Institute of Technology, Swarthmore, and the Princeton Plasma Physics Laboratory have led to significant advances in the understanding of this phenomenon, which is of particular importance in the eruptions of energetic bursts from the surface of the sun, which, in turn affect radio and satellite communications.
- *Understanding the Sharp Edge of the Plasma*: Tokamak plasmas spontaneously generate “transport barriers” that substantially reduce the loss of energy and result in high plasma confinement. When such a barrier forms, the steep pressure gradients that result can give rise to a variety of instabilities. While some instabilities are deleterious, others are benign or even beneficial, as in the regime recently discovered in the Alcator C-Mod tokamak at Massachusetts Institute of Technology, that combines favorable confinement of energetic particles with sufficient particle transport to maintain plasma purity. Installation of high-spatial-resolution diagnostics has enabled measurement, with unprecedented detail, of the plasma profiles in this transport barrier. These measurements are providing critical tests of predictions of stability theory.
- *Relating Plasma Turbulence to the Theory of Avalanches*: Plasma turbulence increases energy transport and thereby limits magnetic confinement. There have been recent attempts to compare plasma transport phenomena with avalanche or “sand pile” transport models. Although plasmas are fluids, Self-Organized Criticality (SOC) models that are used to simulate a wide variety of natural phenomena such as earthquakes, avalanches, etc. describe some nonlinear aspects of plasma turbulence. Measurements of electron temperature and density fluctuations in tokamaks are providing information about the size and frequency of transport events, thus improving comparisons with theoretical avalanche models.
- *Self-Acceleration of the Plasma*: Plasma flows are now known to be critical for improving particle and energy confinement in magnetic confinement configurations. Past experiments have shown that the force exerted on a plasma by injected beams of particles can generate flows through rotation. However, recent observations of rapid rotation in plasmas with radiowave heating rather than beam heating have led to speculation that radiowaves, which do not carry momentum, can also produce rotation. This indicates that it may be possible to use radiofrequency waves to control plasma flow and improve confinement. Focused experiments in Alcator C-Mod now show that even in plasmas

with no additional heating there can be substantial rotation. There is conjecture that this is an intriguing and unexpected effect of turbulent transport.

- *Exploring New Ways to Fuel Fusion Plasmas*: Injecting small pellets of frozen deuterium has long been a technique for fueling fusion plasmas. Usually pellets are launched from the outside, or low magnetic field side, of the tokamaks. But in large, high temperature and high density plasmas this requires extremely high velocity pellets in order to penetrate deep into the plasma core. Recently, pellets injected from the high magnetic field side of the DIII-D tokamak, that is from the center of the "doughnut," penetrated much deeper into the plasma. Analysis of these experiments has helped to uncover key physics missing from earlier pellet penetration codes.
- *New Methods for Starting up Plasmas*: The conventional method for initiating the current in a tokamak—magnetic induction—requires a large transformer winding (or magnet coil) through the center of the tokamak. Non-inductive startup could reduce the size and cost of future fusion devices. By combining edge current drive with the currents driven by radio frequency waves, neutral beam injection, and the bootstrap current generated by plasma pressure itself, calculations have shown that it should be possible to create plasmas in the National Spherical Torus Experiment with currents up to 500,000 amperes. Successful non-inductive startup would permit dispensing with the central magnet, thus simplifying the spherical torus concept enormously.
- *Resolving the Performance Projections for Future Experiments:* Future large-scale fusion devices will require an extrapolation from existing experiments. For several years one of the computer models used for predicting the performance of the International Thermonuclear Experimental Reactor indicated that its performance would be significantly below what empirical extrapolation from present experiments predicts. As a result of concentrated effort by the fusion theorists to understand this difference, it appears that this computer model did not accurately describe certain key physical phenomena. When an improved description of these key physics elements is included in the computer model, there is an increase in the performance projections for ITER, and other large-scale fusion devices, and the expected performance is in the range predicted by a logical empirical extension of present experimental work.
- *MFE Concept Development:* The fusion program is exploring a wide range of confinement concepts other than the tokamak. Three new experiments started operation in FY 1999—the Sustained Spheromak Physics Experiment (SSPX) at the Lawrence Livermore National Laboratory, the flow stabilized pinch experiment (ZAP) at the University of Washington, and the Helically Symmetric Stellarator Experiment (HSX) at the University of Wisconsin. During FY 2000, the Levitated Dipole Experiment at the Massachusetts Institute of Technology will begin operation. This will bring the total number of exploratory level alternate magnetic concept experiments in the United States to 13. This important new investment in the Fusion Energy Sciences program is expected to pay dividends in the form of enhanced understanding of the interaction of plasmas with electric and magnetic fields and lead to significantly better magnetic confinement concepts over the next decade.
- *IFE Concept Development:* There is also increased effort on heavy ion accelerator physics aimed at a driver for inertial fusion. Successful completion of experiments using modular systems would pave the way for the design of an Integrated Research Experiment, a proof-of-principle IFE facility using heavy ions.

Facility Operations Accomplishments

The Fusion Energy Sciences program operates three major facilities for producing high temperature plasmas hotter than the core of the sun: National Spherical Torus Experimental project (NSTX) at PPPL, DIII-D at General Atomics, and Alcator C-Mod at MIT. These facilities are equipped with extensive diagnostic instruments needed to connect experiments to theory and simulation codes. The scientific understanding developed from these facilities is contributing to the knowledge base for an attractive fusion energy source. Modifications and upgrades at these facilities proceeded on schedule and within cost during FY 1999. The combined average unscheduled downtime for these facilities was about 15% in FY 1999. Research on these facilities is augmented and extended through collaboration with international programs.

- The NSTX project at the Princeton Plasma Physics Laboratory (PPPL) was completed in FY 1999, achieving its first major operational milestone ahead of schedule. A national research team was organized and the facility began experimental operations in FY 1999. In FY 2000, one of the TFTR neutral beams will be installed and research operations will resume in mid-summer.
- Significant modifications to the divertor of the DIII-D facility were initiated in FY 1999 and will be completed in early FY 2000, providing capabilities required for experiments to extend the pulse duration of advanced toroidal operating modes later in the year. These important experiments should demonstrate the conditions necessary for long pulse operations.
- Conceptual design of a plasma heating and current drive system for Alcator C-Mod was completed and favorably reviewed in FY 1999. Design and fabrication will begin in FY 2000. Fabrication will continue in FY 2001. The system will be operational in 2002 and will provide significant enhancement of C-Mod plasma performance and duration.
- Preparations for the decontamination and decommissioning (D&D) of TFTR were initiated at PPPL in FY 1999. During FY 2000, PPPL will complete removal of all systems/components to be retained for future use in the program and will prepare the remaining systems/components for dismantling, removal, and shipment offsite. When D&D is completed, the TFTR test cell will be available for reuse by the Fusion Energy Sciences program.

Enabling R&D Accomplishments

- At the direction of Congress, U.S. participation in ITER was successfully completed. The Co-center in San Diego was closed and returned to the owner; U.S. secondees to the Joint Central Team returned; and the U.S. responsibilities in component R&D were discharged. Of particular note, the Central Solenoid Model Coil, the largest pulsed superconducting magnet ever built, was completed and shipped to Japan for testing.
- Bilateral and multilateral plasma technology activities on major scientific facilities abroad continued in order to access test conditions not available on domestic facilities.
- The low activation materials research program continued to focus on feasibility issues and to define and extend operating limits of candidate materials systems.
- All Enabling R&D program elements were fully integrated into a Virtual Laboratory for Technology, thus creating a coordinated national program.
- Research on systems with the potential for significantly increasing high heat flux component performance and lifetime was initiated. Such components will be needed for next generation experiments in several of the developing concepts.

- Research on the magnetic, heating, and fueling components that will enable domestic plasma experiments to achieve their full plasma science research objectives continued.

Awards

- The MIT Plasma Science and Fusion Center, in collaboration with PNNL, won a **1998 R&D 100 Award** for a device that measures smokestack emissions. The award winning work has its roots in fusion diagnostics and plasma physics.
- Five fusion researchers were elected **Fellows of the American Physical Society in 1999.**
- A University of Wisconsin researcher was awarded **the 1999 APS Award for Excellence in Plasma Physics.** This fusion scientist's work focused on the development and exploitation of a diagnostic to measure fluctuations and their relation to energy transport in hot, fusion-relevant plasmas.
- A University of Michigan faculty member received the **1999 IEEE Plasma Science and Application Award**. This fusion-supported researcher studies the scientific aspects of high power radio frequency tubes.
- The MIT Plasma Science and Fusion Center, developed a microplasmatron fuel converter that was selected as one of the **1999 Discover Award** finalists for technological innovation.
- A **U.S. Patent** was awarded to a LANL researcher and to the Regents of the University of California for a diagnostic that measures small temperature changes in fusion plasmas. The diagnostic is in use in Japan and is of interest to European researchers.

Funding of Contractor Security Clearances

In FY 1999, the Department divided the responsibility for obtaining and maintaining security clearances. The Office of Security Affairs, which was responsible for funding all Federal and contractor employee clearances, now pays only for clearances of Federal employees, both at headquarters and the field. Program organizations are now responsible for contractor clearances, using program funds. This change in policy enables program managers to make the decisions as to how many and what level clearances are necessary for effective program execution. In this way, it is hoped that any backlog of essential clearances that are impeding program success can be cleared up by those managers most directly involved. The Office of Science is budgeting $96,000 for estimated contractor security clearances in FY 2000 and FY 2001, within this decision unit.

Workforce Development

The Fusion Energy Sciences program is the Nation's primary sponsor of research in plasma physics and fusion science. The mission of the Fusion Energy Sciences program is to train future researchers not only for fusion research, but also for related areas such as plasma processing, space plasma physics, plasma electronics, and accelerator/beam physics. This program supported 365 graduate students and post doctoral investigators in FY 1999; 49 of these graduate students and post doctoral investigators conducted research at the FES user facilities.

Funding Profile

(dollars in thousands)

	FY 1999 Current Appropriation	FY 2000 Original Appropriation	FY 2000 Adjustments	FY 2000 Current Appropriation	FY 2001 Request
Fusion Energy Sciences					
Science	111,975	141,884	-3,395	138,489	136,202
Facility Operations	61,735	72,950	-1,405	71,545	77,440
Enabling R&D	43,538	35,166	-514	34,652	33,628
Subtotal, Fusion Energy Sciences	217,248	250,000	-5,314	244,686	247,270
Use of Prior Year Balances	-1,136[a]	0	0	0	0
General Reduction	0	-945	+945	0	0
Contractor Travel	0	-1,369	+1,369	0	0
Omnibus Rescission	0	-3,000	+3,000	0	0
Total, Fusion Energy Sciences	216,112[b]	244,686	0	244,686	247,270[c]

Public Law Authorization:

Public Law 95-91, “Department of Energy Organization Act”

Public Law 103-62, “Government Performance Results Act of 1993”

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $5,083,000 which has been transferred to the SBIR program and $305,000 which has been transferred to the STTR program.

[c] Includes $3,157,000 for Waste Management activities at Princeton Plasma Physics Laboratory that was previously budgeted in FY 1999 and FY 2000 in the Environmental Management program.

Funding By Site

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	4,365	6,094	5,960	-134	-2.2%
Sandia National Laboratories	4,120	3,338	3,232	-106	-3.2%
Total, Albuquerque Operations Office	8,485	9,432	9,192	-240	-2.5%
Chicago Operations Office					
Argonne National Laboratory	2,604	2,339	2,270	-69	-2.9%
Princeton Plasma Physics Laboratory	52,129	62,970	70,219	+7,249	+11.5%
Chicago Operations Office	46,304	40,768	39,770	-998	-2.4%
Total, Chicago Operations Office	101,037	106,077	112,259	+6,182	+5.8%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	1,804	1,623	1,701	+78	+4.8%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	4,971	7,877	7,655	-222	-2.8%
Lawrence Livermore National Laboratory	11,696	13,063	12,716	-347	-2.7%
Stanford Linear Accelerator Center	50	50	0	-50	-100.0%
Oakland Operations Office	67,342	67,858	64,453	-3,405	-5.0%
Total, Oakland Operations Office	84,059	88,848	84,824	-4,024	-4.5%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education	471	800	800	0	0.0%
Oak Ridge National Laboratory	18,093	17,550	17,621	+71	+0.4%
Oak Ridge Operations Office	89	87	70	-17	-19.5%
Total, Oak Ridge Operations Office	18,653	18,437	18,491	+54	+0.3%
Ohio Field Office	0	8	0	-8	-100.0%
Richland Operations Office					
Pacific Northwest National Laboratory	1,415	1,385	1,385	0	0.0%
Savannah River Operations					
Savannah River Tech Center	177	0	0	0	0.0%
Washington Headquarters	1,618	18,876	19,418	+542	+2.9%
Subtotal, Fusion Energy Sciences	217,248	244,686	247,270	+2,584	+1.1%
Use of Prior Year Balances	-1,136[a]	0	0	0	0.0%
Total, Fusion Energy Sciences	216,112[b]	244,686	247,270[c]	+2,584	+1.1%

[a] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Excludes $5,083,000 which has been transferred to the SBIR program and $305,000 which has been transferred to the STTR program.

[c] Includes $3,157,000 for Waste Management activities at Princeton Plasma Physics Laboratory that was previously budgeted in FY 1999 and FY 2000 in the Environmental Management program.

Site Description

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. Argonne's Fusion Energy Sciences program contributes to a variety of fusion enabling R&D program activities in areas of modeling, analysis, and experimental research. Argonne has a lead role internationally in analytical models and experiments for liquid metal cooling in fusion devices, including the ALEX facility, that studies the interaction of flowing liquid metals with magnetic fields, and liquid lithium flow loop that studies corrosion in candidate structural alloy materials. Argonne's capabilities in the engineering design of fusion energy systems has contributed to the design of components such as blankets, tritium systems, and plasma-facing components, as well as to analysis supporting the ARIES studies of fusion power plant concepts. Argonne also contributes to low-activation materials research with its unique capabilities in vanadium alloy testing in fission reactors and post-irradiation examinations.

Idaho National Engineering and Environmental Laboratory

Idaho National Engineering and Environmental Laboratory (INEEL) is a Multiprogram Laboratory located on 572,000 acres in Idaho Falls, Idaho. Since 1978, INEEL has been the lead laboratory for fusion safety for the Fusion Energy Sciences program. As the lead laboratory, they have helped to develop the fusion safety data base that will demonstrate the environmental and safety characteristics of both nearer term fusion devices and future fusion power plants. They have focused their research on: (1) understanding the behavior of the sources of radioactive and hazardous materials in a fusion machine, (2) understanding the energy sources in a fusion machine that could mobilize these materials, and (3) developing the analytical tools that demonstrate the environmental and safety characteristics of a fusion machine. In FY 2001, fusion efforts at INEEL will be focused on safety research for magnetic and inertial concepts associated with both existing or planned domestic experimental facilities and the domestic research program. In addition, to develop further our domestic safety data base, INEEL will use existing collaborative arrangements to conduct work on existing international facilities.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory (LBNL) is a Multiprogram Laboratory located in Berkeley, California. The Laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. One of LBNL's missions is to study and apply the physics of heavy ion beams and to advance related technologies for the U.S. Heavy-Ion Fusion (HIF) program. The HIF program centered at LBNL has the long-range goal of developing inertial fusion energy (IFE) as an economically and environmentally attractive source of electric power.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on an 821 acre site in Livermore, California. LLNL is host for Defense Programs' National Ignition Facility, which will give the United States the first opportunity in the world to demonstrate inertial fusion ignition and energy gain in the laboratory. This goal will provide the IFE program with crucial results concerning target physics. This fusion energy mission is consistent with the NIF mission statement. Livermore partners with other Laboratories (LBNL, for example, in Heavy Ion Fusion) in fusion energy research. This program also includes collaborations on the DIII-D tokamak at General Atomics, construction of an innovative concept experiment, the Sustained Spheromak Physics Experiment (SSPX) at LLNL, and benchmarking of fusion physics computer models with experiments such as DIII-D. The SSPX started experimental operations in FY 1999. Definitive results on the feasibility of sustaining high temperature spheromak plasmas utilizing external electrode current drive are expected by the end of FY 2000.

Los Alamos National Laboratory

Los Alamos National Laboratory is a Multiprogram Laboratory located on a 27,000 acre site in Los Alamos, New Mexico. The FY 2001 budget will support the creation of computer codes for modeling the stability of plasmas, as well as work in diagnostics, innovative fusion plasma confinement concepts such as Magnetized Target Fusion, and the successful completion of the research operations of the Tritium Systems Test Assembly (TSTA) facility.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on a 150 acre site in Oak Ridge, Tennessee. ORISE was established by DOE to undertake national and international programs in education, training, health, and the environment. ORISE and its programs are operated by Oak Ridge Associated Universities (ORAU) through a management and operating contract with DOE. Established in 1946, ORAU is a consortium of 88 colleges and universities. For the Fusion Energy Sciences (FES) program, ORISE acts as an independent and unbiased agent to administer the Fusion Energy Sciences Graduate and Postgraduate Fellowship Programs, in conjunction with FES, the Oak Ridge Operations Office (ORO), participating universities, DOE laboratories, and industries.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. ORNL develops a broad range of components that are critical for improving the research capability of fusion plasma experiments located at other institutions and that are essential for developing fusion as an environmentally acceptable energy source. The laboratory is a leader in the theory of heating of plasmas by electromagnetic waves, antenna design, and design and modeling of pellet injectors to fuel the plasma and control the density of plasma particles. Research is also done in the area of turbulence and its effect on transport of heat through a plasma. Codes developed at the laboratory are also used to model plasma processing in industry. While some ORNL scientists are located full-time at off-site locations, others carry out their collaborations with short visits to the host institutions, followed by extensive computer communications from ORNL for data analysis and interpretation, and theoretical studies. ORNL leads the advanced materials program, contributes to research on all materials systems of fusion interest, coordinates experimental collaborations for two U.S.-Japan programs, and coordinates materials activities for the Virtual Laboratory for Technology.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The Fusion Energy Sciences program at PNNL is focused on research on materials that can survive in a fusion neutron environment. The available facilities used for this research include mechanical testing and analytical equipment, including state-of-the-art electron microscopes, that are either located in radiation shielded hot cells or have been adapted for use in evaluation of radioactive materials after exposure in fission test reactors. Experienced scientists and engineers at PNNL provide leadership in the evaluation of ceramic matrix composites for fusion applications and support work on vanadium, copper and ferritic steels as part of the U.S. fusion materials team. PNNL also plays a leadership role in a fusion materials collaboration with Japan, with Japanese owned test and analytical equipment located in PNNL facilities and used by both PNNL staff and up to ten Japanese visiting scientists per year.

Princeton Plasma Physics Laboratory

Princeton Plasma Physics Laboratory (PPPL) is a program-dedicated laboratory (Fusion Energy Sciences) located on 72 acres in Princeton, New Jersey. PPPL is the only U.S. Department of Energy (DOE) laboratory devoted primarily to plasma and fusion science. It hosts experimental facilities used by multi-institutional teams and also sends researchers and specialized equipment to other fusion facilities in the United States and abroad. PPPL is the host for the National Spherical Torus Experiment (NSTX), which is an innovative toroidal confinement device closely related to the tokamak, and is currently working on the conceptual design of another innovative toroidal concept, the compact stellarator. PPPL scientists and engineers have significant involvement in the DIII-D and Alcator C-Mod tokamaks in the U.S. and the large JET (Europe) and JT-60U (Japan) tokamaks abroad. This work is focused on developing the scientific understanding and innovations required for an attractive fusion energy source. PPPL scientists are also involved in several basic plasma science experiments, ranging from magnetic reconnection to plasma processing. PPPL, through its association with Princeton University, provides high quality education in fusion-related sciences, having produced more than 175 Ph.D. graduates since its founding in 1951.

Sandia National Laboratory

Sandia National Laboratory is a Multiprogram Laboratory, with a total of 3,700 acres, located in Albuquerque, New Mexico, with other sites in Livermore, California, and Tonapah, Nevada. Sandia's Fusion Energy Sciences program plays a lead role in developing plasma-facing components for fusion devices through the study of plasma interactions with materials, the behavior of materials exposed to high heat fluxes, and the interface of plasmas and fusion device first walls. Sandia selects, specifies, and develops materials for components exposed to high heat and particles fluxes and conducts extensive analysis of prototypes to qualify components before their use in fusion devices. Materials samples and prototypes are tested in Sandia's Plasma Materials Test Facility, which uses high-power electron beams to simulate the high heat fluxes expected in fusion environments. Materials and components are exposed to tritium-containing plasmas in the Tritium Plasma Experiment. Tested materials are characterized using Sandia's accelerator facilities for ion beam analysis. Sandia supports a wide variety of domestic and international fusion experiments in areas of tritium inventory removal, materials postmortem analysis, diagnostics development, and component design and testing.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center (SLAC) is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California. SLAC is operated for the United States Department of Energy by Stanford University. The main interest in fusion at SLAC is the possibility of adapting the accelerator science and technology from elementary particle physics to the production of fusion power from the implosion of inertial fusion targets driven by beams of high energy, heavy ions. A member of the accelerator research department at SLAC has been involved with the heavy ion fusion program since its inception.

All Other Sites

The Fusion Energy Sciences program funds research at 54 colleges/universities located in 28 states. Also included are funds for DIII-D and related programs at General Atomics and funding of research grants awaiting distribution pending completion of review results or program office detailed planning.

Science

Mission Supporting Goals and Objectives

The goals of the Science subprogram are to advance our understanding of the plasma state and to develop innovative approaches for confining a fusion plasma. These goals are accomplished through a modest program in basic plasma science; active research programs in toroidal concept innovations and non-toroidal concept explorations; strong theory and modeling programs; and the development of improved diagnostics that make possible a rigorous testing of the scientific principles of fusion. A companion objective of the Science subprogram is to broaden the intellectual and institutional base in fundamental plasma physics. Two activities, development activities for junior faculty in plasma physics and an NSF/DOE partnership in plasma physics and engineering, are the major contributors to this objective.

Plasma science is the study of ionized matter, ranging from neon lights to stars, that makes up 99 percent of the observable universe. It includes not only plasma physics but also other physical phenomena in ionized matter, such as atomic, molecular, radiation-transport, excitation, and ionization processes. These phenomena can play significant roles in partially ionized media and in the interaction of plasmas with material walls. Plasma science contributes not only to fusion research, but also to many other fields of national science and technology, including astrophysics, industrial processing, and national security.

Fusion science is focused primarily on describing the fundamental processes in high temperature plasmas (greater than 100,000,000 degrees Celsius) with a confinement parameter (density multiplied by energy confinement time) larger than 10^{20} seconds per cubic meter. Nevertheless, fusion science shares many scientific issues with other topical areas of plasma science. These scientific issues include: 1) wave-particle interaction and plasma heating; 2) chaos, turbulence, and transport; 3) sheaths and boundary layers; and 4) stability, magnetic reconnection, and dynamos. Progress in all of these research issues will be required for ultimate success in achieving a practical fusion energy source.

The largest component of the Science subprogram is the tokamak research activity, that focuses on gaining a predictive understanding of the behavior of high temperature, high density plasmas required for fusion energy applications. All of the major scientific issues of fusion science will be studied in an integrated program on the two major U.S. tokamaks, DIII-D at General Atomics and Alcator C-Mod at the Massachusetts Institute of Technology. DIII-D has been a major contributor to the world fusion program over the past decade in the areas of turbulence and transport, boundary layer/divertor physics, and stability. DIII-D has an extensive set of diagnostics and is focused on developing “advanced toroidal” modes of operation using the flexibility of its plasma shaping and computer control systems. Alcator C-Mod uses intense magnetic fields to explore high temperature and high density plasmas in a unique, compact tokamak facility. Alcator C-Mod has been a major contributor to the world fusion program in the areas of wave-particle interaction/plasma heating and boundary layer/divertor physics.

In addition, advanced tokamak research is carried out by U.S. researchers working on international facilities. The Fusion Energy Sciences program has long followed a policy of not duplicating facilities that exist abroad. More recently, the Fusion Energy Sciences Advisory Committee has recommended that the United States increase collaboration on a number of these unique, state-of-the-art foreign facilities. These include the world’s highest performance tokamaks (JET in England and JT-60 in Japan), a new stellarator (the Large Helical Device) in Japan, a superconducting tokamak (Tore Supra) in France, and several smaller devices. In addition, the U.S. is collaborating with South Korea on the design of a long-pulse, superconducting advanced tokamak (KSTAR). These collaborations provide a valuable link with the 80% of the world's fusion research that is conducted outside the U.S.

Research on alternative confinement concepts, both magnetic and inertial, is aimed at identifying approaches that will extend fusion science and that may improve the economical and environmental attractiveness of fusion energy sources. Since this research is exploratory in nature, much of it is carried out on small "concept exploration" experiments; however, a few concepts are sufficiently advanced for medium-size "proof-of-principle" experiments.

Concept exploration experiments typically focus on energy transport and/or plasma stability. These two issues are critical for improved economic attractiveness. Proof-of-principle experiments continue to study these two issues; however, they also begin to focus on wave-plasma interaction, plasma heating, and boundary layer physics.

The first alternate concept proof-of-principle experiment, the new National Spherical Torus Experiment (NSTX) facility at the Princeton Plasma Physics Laboratory (PPPL), began its first full year of operation in FY 2000, with a goal of demonstrating improved plasma stability and confinement in a very compact structure. The Madison Symmetric Torus (MST) at the University of Wisconsin was favorably reviewed by the Fusion Energy Sciences Advisory Committee, and is being upgraded to the proof-of-principle level. A number of concept exploration experiments are in operation or nearly ready to begin operation at various laboratories and universities around the country.

The Inertial Fusion Energy (IFE) activity is exploring an alternate path for fusion energy that would capitalize on the major R&D effort in inertial confinement fusion (ICF) carried out for stockpile stewardship purposes within the Office of Defense Programs. The IFE program depends on the ICF program for experimental research into the physics of target ignition that will be tested in the National Ignition Facility at LLNL. Efforts in IFE focus on understanding the physics of systems or techniques that will be needed to produce a viable inertial fusion energy source. These include the heavy ion beam systems for heating and compressing a target pellet to fusion conditions, the experimental and theoretical scientific basis for modeling target chamber responses, and high-gain target design.

Theory and modeling are essential to progress in fusion and plasma science because they provide the central organizing concepts of the field. They also provide the capability to analyze existing experiments, produce new ideas to improve performance, and provide a scientific assessment of new ideas. An important component of the theory program is the development and use of advanced computational tools to model the complex physical phenomena that govern confinement of high temperature plasmas. Such tools will be necessary to provide a predictive understanding of complex, highly nonlinear fusion systems.

Similarly, the development and improvement of diagnostic tools for analyzing plasma behavior continues to provide new insights into fusion plasmas and enables the detailed comparison of fusion theory and experiments.

Performance Measures

- Sustain partnerships that support fusion/plasma sciences, specifically through completion by June 2001 of a new NSF/DOE Partnership in Basic Plasma Science and Engineering to provide continuity after the present agreement ends, and by initiating a new element of the U.S.-Japan collaborative program by the end of FY 2001.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Tokamak Experimental Research	45,824	47,561	44,456	-3,105	-6.5%
Alternative Concept Experimental Research	37,263	53,243	50,299	-2,944	-5.5%
Theory	22,666	24,536	27,536	+3,000	+12.2%
General Plasma Science	6,222	7,964	8,450	+486	+6.1%
SBIR/STTR	0[a]	5,185	5,461	+276	+5.3%
Total, Science	111,975	138,489	136,202	-2,287	-1.7%

Detailed Program Justification

(dollars in thousands)

FY 1999	FY 2000	FY 2001

Tokamak Experimental Research

- **DIII-D Research:** The DIII-D facility at General Atomics is directed towards the investigation of the physics of Advanced Tokamak concepts. Since the early 1990s, the experimental results from DIII-D and other tokamaks worldwide have shown that the use of detailed plasma control techniques such as selective heating, fueling, and current drive impacts the performance of tokamak plasmas considerably. The underlying physical processes that affect tokamak performance are complex and require extensive diagnostics and theoretical support to understand them. DIII-D, the largest U.S. fusion experiment, is extensively equipped with diagnostics to investigate these challenging scientific issues with a large group of collaborators from the many U.S. and international fusion groups. In FY 2001, initial results will be obtained on Advanced Tokamak integration (optimizing transport, power exhaust, profile control simultaneously) using the upgraded current drive and

[a] Excludes $4,020,000 which has been transferred to the SBIR program and $241,000 which has been transferred to the STTR program.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
power exhaust systems and a wide range of diagnostics. These results will be analyzed using the latest theory and modeling to evaluate the future scientific path for Advanced Tokamaks..	21,931	23,025	21,617
■ **Alcator C-Mod Research:** The Alcator C-Mod facility, by virtue of its very high magnetic field, is particularly well suited to operate in plasma regimes which are relevant to future much larger fusion tokamaks as well as compact, high field ignition tokamaks. The approach to ignition and sustained burn of a plasma is an important scientific issue for fusion. In FY 2001, Alcator C-Mod will address issues relevant to the confinement and heating of ignition tokamaks. It will also examine the physics of the plasma edge, power and particle exhaust from the plasma, mechanisms of self-generation of flows in the plasma, and improved confinement modes with currents driven by radio waves. New diagnostics made possible by the commissioning of a new diagnostic neutral beam in FY 2000 will be available in FY 2001. These new diagnostics will allow for improved comparisons between theory and experimental results.	7,775	7,870	7,367
■ **International Collaborations and Education:** International collaboration at the level of $4,329,000 provides the opportunity for U.S. scientists to work with their colleagues on unique foreign tokamaks (JET, Tore Supra, TEXTOR, and ASDEX-UG in Europe, JT-60U in Japan, and K-STAR in Korea). These collaborations produce complementary and comparative data to those obtained on the U.S. tokamaks to further the scientific understanding of fusion physics and enhance the pace of fusion energy development. In FY 2001, the collaboration with these programs will focus on the physics of Advanced Tokamaks, Burning Plasmas, and long pulse physics issues. The remaining $4,118,000 is required primarily for graduate and postgraduate fellowships in fusion science and technology, summer internships for undergraduates, general science literacy programs with teachers and students, support for historically black colleges and universities, and similar broad outreach efforts related to fusion science and technology.	8,495	9,181	8,447
■ **Experimental Plasma Research (Tokamaks):** Several unique, innovative tokamak experiments are supported at leading universities. These focus on various topics, including advanced toroidal operating modes and plasma stability and control. The Electric Tokamak at UCLA will begin research			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
operation. This program also develops unique diagnostic probes that provide an understanding of the plasma behavior in fusion research devices, supplying the necessary information for analysis codes and theoretical interpretation. Some key areas of diagnostic research include: 1) techniques to measure temperature and density profiles and fluctuations in these profiles to provide a better understanding of transport and 2) methods to measure the production and confinement of alpha particles to prepare for future burning plasma experiments. The requested funding level in FY 2001 supports the core diagnostic development research, as well as the work begun as a result of an FY 1999 competitive initiative to develop new diagnostic techniques..........................	7,623	7,485	7,025
Total, Tokamak Experimental Research...	45,824	47,561	44,456
Alternative Concept Experimental Research			
■ **NSTX Research:** The NSTX at PPPL will complete the first year of scientific research in FY 2000. The research program, that is carried out by a national team made up of PPPL and other laboratory and university researchers, includes plasma formation, methods of controlled startup, plasma heating by radiofrequency waves and diagnostic implementation. Research in FY 2001 will pursue noninductive assisted startup at high currents and test stability properties of the spherical torus configuration...	9,906	12,874	12,250
▪ **Experimental Plasma Research (Alternates):** This budget category includes most of the experimental research on plasma confinement configurations outside of the three large fusion facilities described elsewhere. It consists of twelve smaller experiments (concept exploration level [CE]), one intermediate level experiment (proof-of-principle [PoP]) and one large study program that is focused on obtaining a design for another Proof-of-Principle experiment – a compact stellarator.			
The majority of the research is directed toward toroidal configuration with nested magnetic surfaces. For configurations with a large toroidal magnetic field, the research is focused on stellarators with special symmetry properties. The Helically Symmetric Torus, now operating at the University of Wisconsin, is the world's first stellarator designed using these symmetry principles. There is also another large effort underway, that is studying the design of a			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Proof of Principle level stellarator with symmetry properties similar to those of the tokamak but without externally driven plasma current. Also, in this category are two very low aspect ratio concept exploration level spherical tokamak experiments (Helicity Injection Tokamak at the University of Washington and the Pegasus Experiment at the University of Wisconsin), which will study the physics of toruses with only a very small hole in the middle. Such configurations stretch conventional stability theory into unexplored regimes. Research on configurations where the toroidal field is less than the poloidal field concentrates on magnetic turbulence and reconnection. This program includes Madison Symmetric Torus (University of Wisconsin), a concept exploration level experiment at LLNL, and a small experiment at California Institute of Technology designed to study basic physics of the reconnection process itself. Research on toroidal systems with closed magnetic field lines concentrates on systems where the lines close upon themselves the short way around (poloidally) the torus. The field reversed configuration (FRC) experiment at the University of Washington, the world's most advanced experiment of this type, focuses on stability issues. The ion ring experiment at Cornell University seeks gross stabilization of the FRC through the use of large ion orbits. The levitated dipole experiment (LDX) at MIT studies a variant where the confining poloidal magnetic fields are generated by a superconducting magnetic ring located within the plasma itself. Dipole confinement is of great importance in many solar and astrophysical systems. The magnetized target fusion program (funded by the FES program) at LANL and the Air Force Research Laboratory will study the possibility that a FRC can be compressed to multi-keV temperatures using fast liner technology developed by the defense programs.	18,980	25,088	23,665
■ **Inertial Fusion Energy Experiments:** The inertial fusion energy program has research components that encompass many of the scientific and technical elements that form the basis of an inertial fusion energy system. Heavy ion accelerators continue to be the leading candidate driver. Understanding the physics of the heavy ion beam, that is a non-neutral plasma, is one of the outstanding scientific issues. Considerable progress has been made on developing a			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
model for the accelerator, with the goal of providing a predictive "end-to-end" capability. The elements of this model must be compared to experimental results, and this effort will continue. Technical elements of the program include the continuing development of experimental systems to study beam formation, acceleration and focussing. The design of fusion energy targets will continue, benefiting from presently available high energy density physics data. Physics experiments to be carried out on Defense Programs' National Ignition Facility will ultimately provide validation of target design. Emphasis will be maintained on critical scientific research topics that, even with reduced efforts, will allow modest progress to be made in developing the scientific and technical foundations of inertial fusion energy.	8,377	15,281	14,384
Total, Alternative Concept Experimental Research..........................	37,263	53,243	50,299

Theory

- The theoretical problems in plasma science are formidable. The goal of the theory and computation program is to achieve a quantitative understanding of the behavior of fusion plasmas. Considerable progress has been made in areas such as the macroscopic equilibrium and stability of magnetically confined plasmas and turbulence and transport in tokamak plasmas. The theory and computing program is a broad-based program with researchers located at national laboratories, universities, and industry. There is an increased program emphasis on advanced computing, including the development of improved modeling codes and a code library for use by all fusion researchers. Work in tokamak theory includes not only efforts to support analysis of experiments, but also includes the development of many new theories and tools that model plasma behavior in advanced tokamaks. These tools will later be extended to innovative confinement geometries. The majority of the work in toroidal theory is aimed at developing a predictive understanding of advanced tokamak operating modes. In alternate concept theory, the emphasis will be on understanding the fundamental processes determining equilibrium, stability, and confinement in each concept. Generic theory supports the development of basic plasma theory and atomic physics theory that is applicable not only to fusion research, but also to basic plasma science. The objective of the advanced computing activity is to improve computational simulation

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
and modeling capabilities in order to obtain a quantitative understanding of plasma behavior in fusion experiments. This will ensure optimum use of a set of innovative national experiments and fruitful collaboration on major international facilities. In FY 2001, funds will be used to develop improved models of equilibrium and stability and turbulence and energy transport in toroidal magnetic confinement systems and to improve the fidelity of heavy ion accelerator models. The Fusion Energy Sciences program will select the research projects on advanced simulation and modeling of fusion plasma systems using a competitive peer review process...........	22,666	24,536	27,536
General Plasma Science			
■ The plasma science program focuses on basic plasma science and, engineering research. This research is carried out primarily by the University community, but DOE laboratories are expected to make contributions as well. Advances in basic plasma physics contribute to the foundation of the Fusion Energy Sciences program as well as other important areas of science and technology. This program provides a strong contribution to the education of plasma physicists. The Plasma Science Junior Faculty Development Program will continue at FY 2000 levels. Collaborative efforts such as the NSF/DOE plasma science and engineering program will continue. In FY 2000 opportunities were made available to DOE laboratory plasma scientists to compete for funding for basic and applied plasma physics research. Laboratory scientists form an important component of the general plasma science community. They also operate unique user facilities such as the Magnetic Reconnection Experiment (MRX) at PPPL. In FY 2001, laboratory activities will be maintained at a constant level. The program will also continue to collect and distribute atomic physics data for fusion.	6,222	7,964	8,450
SBIR/STTR			
■ In FY 1999, \$4,020,000 and \$241,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	5,185	5,461
Total, Science..	111,975	138,489	136,202

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Tokamak Experimental Research	
■ The level of participation by the collaborators and on site staff in physics research and data analysis will decrease on DIII-D.	-1,408
■ Participation of offsite collaborators and development of diagnostics will decrease on Alcator C-Mod	-503
■ There is a decrease in diagnostic development within Tokamak Experimental Plasma Research.	-460
■ This decrease primarily results from decreased effort in international collaboration on medium-size tokamaks.	-734
Total, Tokamak Experimental Research	-3,105
Alternative Concept Experimental Research	
■ The decrease in support for NSTX research will impact data collection and analysis, and funds for enhancement of existing research collaborations and preparation of advanced diagnostics	-624
■ Funding for alternate concepts experiments is reduced.	-1,423
■ The IFE program is reduced to fund other fusion program priorities. Programmatic emphasis will be placed on scientific areas which will enable progress to be made in the development of the scientific and technical foundations of inertial fusion energy.	-897
Total, Alternative Concept Experimental Research	-2,944
Theory	
■ The theory program will include increased effort on advanced computational simulation and modeling of complex fusion systems.	+3,000
Basic Plasma Science	
■ Increased funding in basic plasma science will be directed to the support of user facilities in basic plasma science	+486
SBIR/STTR	
■ Support for SBIR/STTR is mandated at 2.65 percent. These grants will support plasma and fusion science.	+276
Total Funding Change, Science	-2,287

Facility Operations

Mission Supporting Goals and Objectives

This activity provides for the operation and maintenance of major fusion research facilities; namely, DIII-D at GA, Alcator C-Mod at MIT, and NSTX at PPPL. These user facilities enable U.S. scientists from universities, industry, and laboratories, as well as visiting foreign scientists, to conduct world-class research on the behavior of fusion plasmas. The facilities consist of magnetic plasma confinement devices, plasma heating and current drive systems, diagnostics and instrumentation, experimental areas, computing and computer networking facilities, and other auxiliary systems. This activity includes the cost of operating and maintenance personnel, electric power (about 3% of the total operating cost at a research facility), expendable supplies, replacement parts, subsystem modifications and enhancements, and inventories. In the case of PPPL, funding is provided for continuing the decontamination and decommissioning of the Tokamak Fusion Test Reactor, which was shut down in FY 1997; ongoing caretaking for the tritium systems and radioactive elements is also required during this process. In addition, in FY 2001, the Fusion Energy Sciences program will take over waste management activities from the Environmental Management (EM) program for the PPPL site. General plant projects (GPP) funding for PPPL supports minor facility renovations and other capital alterations and additions for buildings and utility systems. Capital equipment funding for upgrading the research capability of DIII-D and C-Mod is also included to further enhance the facilities.

The principal objective of the Facility Operations subprogram is to maximize the quantity and quality of data collected at the major fusion energy science facilities while complying with all applicable safety and environmental requirements and cultivating an environment of operational excellence.

The following table summarizes the scheduled weeks of operations for DIII-D, C-Mod, and NSTX.

Performance Measures

- Complete by June 2001 the 6 MW power upgrade of the DIII-D microwave system and initiate experiments with it to control and sustain plasma current profiles, with the goal of maintaining improved confinement of plasma energy for longer periods of time.
- Initiate and meet schedules for dismantling, packaging, and offsite shipping of the Tokamak Fusion Test Reactor (TFTR) systems.

Facility Utilization

(Weeks of Operations)

	FY 1999	FY 2000	FY 2001
DIII-D	14	14	17
Alcator C-Mod	12	18	14
NSTX	6	14	17

Funding Schedule

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
TFTR	3,949	13,422	19,600	+6,178	+46.0%
DIII-D	29,065	31,098	29,255	-1,843	-5.9%
Alcator C-Mod	10,223	10,657	10,042	-615	-5.8%
NSTX	17,022	15,406	14,469	-937	-6.1%
General Plant Projects/Other	1,476	962	917	-45	-4.7%
Waste Management	0	0	3,157	+3,157	+100.0%
Total, Facility Operations	61,735	71,545	77,440	+5,895	+8.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
TFTR			
■ Continue the decontamination and decommissioning (D&D) of TFTR ($16,000,000). This activity will provide for the removal and disposal of the tokamak and remaining radioactive components from the test cell and the basement. In addition, during the D&D, $3,600,000 is necessary to maintain and keep the facility safe.	3,949	13,422	19,600
DIII-D			
■ Provide support for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems, such as the Electron Cyclotron Heating (ECH) systems, developed by the Enabling R&D subprogram. In FY 2001, these funds support 17 weeks of plasma operation during which time fusion research experiments will be conducted. The fabrication and installation of the 6 megawatt, 110 GHz ECH system will be completed in FY 2001.	29,065	31,098	29,255

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Alcator C-Mod			
■ Provide support for operation, maintenance and minor machine improvements. In FY 2001, these funds support 14 weeks of plasma operation during which time fusion research experiments will be conducted. Design and construction of the Lower Hybrid Current Drive System will continue. This is a Major Item of Equipment with a TEC of $4,200,000 that will be initiated in FY 2000.	10,223	10,657	10,042
NSTX			
■ Provide continuation of operational activity on the NSTX experiment and installation of planned diagnostic upgrades. These funds support 17 weeks of plasma operation during which time fusion research experiments will be conducted.	8,122	12,906	14,469
■ **NSTX Project:** Project completed in FY 1999 and facility begins operations.	5,450	0	0
■ **NSTX Neutral Beam:** The NSTX neutral beam modification will be completed in FY 2000 and will be integrated into the NSTX research facility for use in FY 2001 research programs.	3,450	2,500	0
Total, NSTX	17,022	15,406	14,469
General Plant Projects/Other			
■ These funds provide primarily for general infrastructure repairs and upgrades for the PPPL site.	1,476	962	917
Waste Management			
■ These funds provide the support necessary to handle all waste management activities at the PPPL site	0	0	3,157
Total, Facility Operations	61,735	71,545	77,440

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
TFTR	
■ Decommissioning of TFTR proceeds on schedule for completion in 2002	+6,178
DIII-D	
■ Operating time of DIII-D is increased by 3 weeks and modest refurbishments are carried out	+3,050
■ The heating system upgrade modification to DIII-D is completed in FY 2001	-4,893
Total, DIII-D	-1,843
Alcator C-Mod	
■ Modifications to the device's heating system will be delayed and operating time decreased by 4 weeks.	-615
NSTX	
■ Support for operating the heating systems on NSTX is increased and operating time is increased by 3 weeks.	+1,563
■ Decrease due to completion of NSTX neutral beam heating system fabrication project in FY 2000	-2,500
Total, NSTX	-937
GPP/Other	
■ Completion of ongoing repairs will continue at essentially the FY 2000 level	-45
Waste Management	
■ Responsibility for waste management activities at the PPPL site has been transferred to the Fusion Energy Sciences program from the Environmental Management program in FY 2001. These funds are being transferred to the program in order to provide an incentive for the laboratory to minimize the amount of waste they produce.	+3,157
Total Funding Change, Facility Operations	+5,895

Enabling R&D

Mission Supporting Goals and Objectives

For sustained progress toward ultimate research goals, science-oriented programs that push the frontiers of human knowledge, such as fusion, require intellectual resources, experimental facilities with state-of-the-art technological capabilities, and continuing technology innovations. The Enabling R&D subprogram provides for such progress in both magnetic and inertial fusion energy research. This subprogram is divided into two elements: Engineering Research and Materials Research.

The Engineering Research element underwent a major restructuring in FY 1999 when the U.S. stopped participating in the International Thermonuclear Experimental Reactor project. The scope of activities has been substantially broadened to address more fully the diversity of domestic interests in enabling R&D for both magnetic and inertial fusion energy systems. These activities now focus on critical technology needs for enabling U.S. plasma experiments to achieve their full performance capability. Also, international technology collaborations allow the U.S. to access plasma experimental conditions not available domestically. These activities also include investigation of the scientific foundations of innovative technology concepts for future experiments. Another activity is advanced design of the most scientifically challenging systems for next step fusion research facilities, i.e. facilities that may be needed in the immediate future. Also included are analysis and studies of critical scientific and technological issues, the results of which will provide guidance for optimizing future experimental approaches and for understanding the implications of fusion research on power plant applications. Major FY 1999/2000 accomplishments include: completed fabrication of the world's largest pulsed superconducting magnet coil, and shipped it for testing in a Japanese facility; completed fabrication and testing of both a prototype actively cooled, high surface heat flux divertor system and a robotic vacuum vessel welding system; and demonstrated world record performance levels for a plasma heating microwave power tube.

The Materials Research element continues to focus its scientific research on low-activation materials, that have high performance capability and can withstand long-term exposure to the energetic particles and electromagnetic radiation expected from energy-producing plasmas. Efforts continued on mapping of irradiation effects on candidate low-activation alloys, that will be used to set priorities for future research. Recommendations provided in an FY 1998 FESAC review were followed by strengthening the modeling and theory component of materials research, by greater integration with other fusion program elements, and by expansion to include conditions and materials of interest to both magnetic and inertial fusion energy systems.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Engineering Research	36,698	26,578	25,943	-635	-2.4%
Materials Research	6,840	7,167	6,804	-363	-5.1%
SBIR/STTR	0[a]	907	881	-26	-2.9%
Total, Enabling R&D	43,538	34,652	33,628	-1,024	-3.0%

Detailed Justification

(dollars in thousands)

	FY 1999	FY 2000	FY 2001
Engineering Research			
■ Plasma Technology efforts will be focused on critical needs of domestic plasma experiments and on the scientific foundations of innovative technology concepts for use in both future magnetic and inertial fusion experiments and attractive fusion energy sources. Nearer-term experiment support efforts will be oriented toward plasma facing components and plasma heating and fueling technologies. Longer-term efforts will be oriented toward superconducting magnet research to reduce magnet costs and improve their reliability.	19,475	12,085	11,664
■ Fusion Technology will be focused on technology innovations and model improvements needed to resolve critical issues faced by inertial fusion concepts and possibly magnetic concepts as well. These issues include the vacuum chamber as well as tritium and safety research that are critical to the safety and environmental attractiveness of all fusion systems. In the tritium area, TSTA will complete its mission in FY 2001 and research will cease, while tritium inventory reduction will continue in preparation for decommissioning. Management of all of the diverse collection of fusion technologies will be accomplished through a Virtual Laboratory for Technology whereby community-based coordination and communication of plans, progress, and results will be accomplished through the use of modern information technology.	8,096	9,222	9,373

[a] Excludes $1,063,000 which has been transferred to the SBIR program and $64,000 which has been transferred to the STTR program.

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
■ Advanced Design and Analysis will be modestly reduced and redirected to include design of the most critical systems for fusion research facilities that may be needed in the near future, and analysis of cost-effective research pathways.	9,127	5,271	4,906
Total, Engineering Research..	36,698	26,578	25,943
Materials Research			
■ Materials research remains a key element in developing a safe, reliable, and environmentally attractive fusion energy system. Scientific understanding and the development, research, and testing of vanadium alloys, silicon carbide composite materials, and advanced ferritic steels for structural service in the high power zones for fusion energy sources will continue. Priorities for this work, including innovative approaches to evaluating materials and improved modeling of materials behavior, are guided by the results of a Fusion Energy Sciences Advisory Committee review conducted during 1998 and include materials and conditions relevant to inertial fusion systems as well as magnetic systems	6,840	7,167	6,804
SBIR/STTR			
■ In FY 1999, $1,063,000 and $64,000 were transferred to the SBIR and STTR programs, respectively. The FY 2000 and FY 2001 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	907	881
Total, Enabling R&D...	43,538	34,652	33,628

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Engineering Research	
■ Plasma Technology is decreased in the areas of magnetics and plasma facing components	-421
■ Fusion Technology is increased to include additional efforts on inertial fusion tasks	+151
■ Advanced Design and Analysis effort is reduced and will be focused on selected critical topics.	-365
Total Engineering Research	-635
Materials Research	
■ Research on modeling of materials will be reduced.	-363
SBIR/STTR	
■ Requirements reduced as Enabling R&D is decreased.	-26
Total Funding Change, Enabling R&D	-1,024

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
General Plant Projects	1,165	862	822	-40	-4.6%
Capital Equipment	17,475	13,946	7,115	-6,831	-49.0%
Total, Capital Operating Expenses	18,640	14,808	7,937	-6,871	-46.4%

Major Items of Equipment *(TEC $2 million or greater)*

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1999	FY 2000	FY 2001	Accept-ance Date
DIII-D Upgrade	27,367	17,437	4,023	5,400	507	FY 2001
NSTX	21,100	15,650	5,450	0	0	FY 1999
NSTX – Neutral Beam	5,950	0	3,450	2,500	0	FY 2000
Alcator C-Mod LH Modification	4,200	0	0	1,120	1,864	FY 2002
Total, Major Items of Equipment		33,087	12,923	9,020	2,371	

Science Program Direction

Program Mission

This program provides the Federal staffing and associated funding required to provide overall direction of activities carried out under the following programs in the Office of Science (SC): High Energy Physics, Nuclear Physics, Biological and Environmental Research, Basic Energy Sciences, Fusion Energy Sciences, Computational and Technology Research, Multiprogram Energy Laboratories-Facilities Support, and Energy Research Analyses. This funding also provides the necessary support to the Director of SC to carry out SC's responsibilities under the Department of Energy (DOE) Organization Act (P.L. 95-91) and as mandated by the Secretary. These responsibilities include providing advice on the status and priorities of the Department's overall research and development programs and on the management of the Department's multipurpose laboratories; developing research and development plans and strategies; supporting university and science education; and ensuring the institutional health and overall site integration at three multi-program field offices. This program also provides program-specific staffing resources at the Chicago, Oakland, and Oak Ridge Operations Offices directly involved in executing SC programs.

The Program Direction subprogram has been divided into four categories: Salaries and Benefits, Travel, Support Services, and Other Related Expenses, the latter including the Working Capital Fund. “Support Services” refers to support services contracts that provide necessary support functions to the Federal staff, such as technical support, computer systems development, travel processing, and mailroom activities. “Other Related Expenses” refers to other administrative costs of maintaining Federal staff, such as building and facility costs and utilities in the field, information technology expenses, and training. The Working Capital Fund includes centrally provided goods and services at Headquarters, such as supplies, rent and utilities.

The Science Education subprogram focuses primarily on undergraduate research experiences at the national laboratories. Science Education also supports the Albert Einstein Distinguished Educator Fellowships, the National Science Bowl, and the DOE Institute of Biotechnology, Environmental Science, and Computing for Community Colleges.

The Energy Research Undergraduate Laboratory Fellowships, formerly known as the Laboratory Cooperative Program, are designed to provide educational training and research experiences at DOE laboratories for highly motivated undergraduate students. These opportunities complement academic programs and introduce students to the unique intellectual and physical resources present at the DOE laboratories. Appointments are available during the spring, summer, and fall terms.

In 1991, as a national initiative, the National Science Bowl was developed to encourage high school students from across the Nation to excel in math and science and to pursue careers in those fields. It provides students and their teachers a forum to receive national recognition for their talent and hard work. DOE is committed to math and science education to help provide a technically trained and diverse workforce for the Nation. The National Science Bowl is a highly publicized academic competition among teams of high school students who answer questions on scientific topics in astronomy, biology, chemistry, mathematics, physics, earth, computer and general science. Since its inception, more than 60,000 high school students have participated in regional tournaments leading up to the national finals.

The Albert Einstein Distinguished Educator Fellowship Act of 1994 was signed into law in November 1994. The law gives DOE responsibility for administering the program of distinguished educator fellowships for elementary and secondary school mathematics and science teachers. This program supports outstanding teachers of science and mathematics, who provide insights, extensive knowledge and practical experience to the Legislative and Executive branches.

The DOE Institute of Biotechnology, Environmental Science, and Computing for Community Colleges is a collaboration between DOE (and five of its multiprogram laboratories) and the American Association of Community Colleges. It is designed to provide educational training and research experiences at five DOE national laboratories for highly motivated community college students. Each laboratory will offer a ten-week summer experience for selected students from a regional consortium of community colleges partnering with DOE and that laboratory.

The Field Operations subprogram enables three Operations Offices to provide the managerial, business, fiduciary, contractual, and technical foundation necessary to support the programmatic missions performed in support of science and technology, national security, energy research, and environmental management. These resources provide for the administrative staff, technical experts, and operational requirements that support the direct program activities at Chicago, Oak Ridge, and Oakland, and the laboratories and facilities under their purview.

Program Goal

- Fund the staff and related expenses needed to provide overall management direction of SC's basic and fundamental scientific research programs funded in the Science appropriation.
- Enable the Director of SC to serve as the Department's science advisor for formulation and implementation of basic and fundamental research policy.
- Sustain U.S. leadership in science, technology, and engineering by leveraging DOE resources in partnership with laboratories and facilities that contribute to the development of a diverse scientific and technical workforce for the 21st century.
- Provide management and administrative services, at reduced costs through consolidation and re-engineered processes, that enable the Chicago, Oakland and Oak Ridge Operations Offices to continue environmental cleanups; reduce surplus weapons' inventory; support the national laboratories and research facilities; institute environmental, safety and health initiatives.
- Maintain communications with stakeholders.
- Create public and private partnerships.
- Take advantage of reindustrialization opportunities.

Program Objectives

Program Direction

- To develop, direct and administer a complex and broadly diversified program of mission-oriented basic and applied research and development designed to support new and improved energy, environmental and health technologies.
- To manage the design, construction, and operation of forefront scientific research facilities for use by the Nation's scientific community, including the Spallation Neutron Source Project.
- To conduct independent technical assessments, peer reviews and evaluations of research proposals, programs and projects.
- To enhance international collaboration and leverage the U.S. investment in research and development.
- To review, analyze and, where appropriate, champion the recommendations of SC's Federally chartered advisory committees, including the Fusion Energy Sciences Advisory Committee, High Energy Physics Advisory Panel, Nuclear Science Advisory Committee, Basic Energy Sciences Advisory Committee, Biological and Environmental Research Advisory Committee, and Advanced Scientific Computing Advisory Committee.

Science Education

- To provide opportunities and effective mechanisms for students and faculty to participate at the Department's laboratories in hands-on research experiences, related to SC's research programs, with a focus on undergraduates.

Field Operations

- To provide the day-to-day managerial, business, fiduciary, contractual, and technical foundation necessary to support programmatic missions in the areas of science and technology, national security, energy research, and environmental management.
- To improve the efficiency of operations through development and implementation of integrated business management systems.
- To maintain the field infrastructure in an environment that is safe and hazard free.
- To improve communications with customers, stakeholders, and the public.

Performance Measures

Program Direction

- Responsiveness to national science policy and major science initiatives.

- Improvement in environment, safety, and health compliance and reduction of waste generation and environmental emissions.
- Make provisions for new and/or enhanced research facilities and equipment within scope and budget and on schedule.
- Continue improvements in the utilization of staffing, travel, and support contractor funds.
- Continue to improve levels of facility operating time.
- Expand international collaborative efforts.
- Cost share and leverage program resources with other agencies on a one-to-one basis to multiply the program's impact.

Science Education

- Increase the flow of underrepresented students up to 50 percent into science and math programs/careers.

Field Operations

- Award management and operating contract for the Y-12 Plant.
- Realize cost avoidance of at least 10 percent by consolidating the development of information systems and network architecture, and acquisition of information technology.
- Automate budget transmissions between the contractor/laboratories, the Operations Offices, and Headquarters.

Significant Accomplishments and Program Shifts

Program Direction

- SC Headquarters continues to achieve technical excellence in its programs despite managing one of the largest, most diversified and most complex basic research portfolios in the Federal Government with a relatively small Federal and contractor support staff.
- Concluded the international agreement for U.S. participation in the Large Hadron Collider project. Signatories included the Secretary of Energy and the Director of the National Science Foundation. Execution of the project is ongoing.
- Continue operation of the William R. Wiley Environmental Molecular Sciences Laboratory at Pacific Northwest National Laboratory.
- At Fermilab, completed construction of the C-Zero Experimental Hall within scope and budget, and on schedule (FY 1999 completion); and completed the Main Injector within scope and budget, and on schedule (FY 1999 initial operation).
- Completed the B-factory and its detector at the Stanford Linear Accelerator Center within scope and

budget, and on schedule (FY 1999 initial operation).

- Enhance the scientific capabilities for experiments at the Thomas Jefferson National Accelerator Facility (TJNAF) to provide new opportunities for researchers. Three TJNAF experimental halls will be fully operational.
- Carry out experiments at the Radioactive Ion Beam facility at Oak Ridge National Laboratory.
- Transfer of management responsibility from Environmental Management to Science for newly generated wastes at Ames, Argonne National Laboratory/East, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, Pacific Northwest National Laboratory, and Princeton Plasma Physics Laboratory.
- Manage the Joint Genome Institute and the Atmospheric Radiation Measurement sites using the national laboratories as an integrated system.
- Strengthen integrated safety and security management and infrastructure management at the national laboratories.
- Operate the state-of-the-art National Energy Research Scientific Computing and Energy Science Network for the benefit of SC and DOE.
- Plan and manage a complex, scientific R&D program to establish the knowledge base needed for an attractive fusion energy source.
- Continue to refine framework of appropriate international arrangements needed to carry out SC programs in a most cost-effective manner.
- Continue enhancement of neutron science capability at the Los Alamos Neutron Science Center and the High Flux Isotope Reactor at Oak Ridge.
- Continue design and construction of the Neutrinos at the Main Injector project.
- Accomplished the U.S. withdrawal from the International Thermonuclear Experimental Reactor program consistent with congressional direction and appropriated funds while preserving effective working relationships with affected U.S. institutions.
- Completed the National Spherical Torus Experiment at the Princeton Plasma Physics Laboratory within scope and budget (FY 1999), achieving first plasma milestone ahead of schedule.
- Completed the assessment of the quality of fusion science requested by the Office of Science and Technology Policy and carried out by the National Research Council of the National Academy of Sciences.
- The Office of Fusion Energy Sciences will respond to recommendations from the Secretary of Energy Advisory Board review of DOE fusion energy programs and the Fusion Energy Sciences Advisory Committee report on opportunities and requirements of fusion energy.
- Began construction of the Spallation Neutron Source Project Office at Oak Ridge National Laboratory in FY 2000.

Science Education

- The Energy Research Undergraduate Laboratory Fellowship Program has implemented an innovative, interactive Internet system to receive and process hundreds of student applications for summer and semester research appointments at 11 participating DOE laboratories. The automated system is virtually paperless and provides an excellent example of how the Internet can be used to streamline the operation of the Department's research participation programs.
- Through special recruitment efforts, the Energy Research Undergraduate Laboratory Fellowship Program has attracted a diverse group of students using the electronic application. Nearly 20 percent of those submitting applications were from underrepresented ethnic groups. About 40 percent of the applications were from females, and more than 25 percent were from low-income families. More than 600 summer 1999 appointments were made through the new application process.
- Five additional regional competitions were held in conjunction with DOE's National Science Bowl. More than 9,000 high school students participated in the 53 regional science bowl tournaments.
- The Albert Einstein Distinguished Educator Fellowship awards to pre-college science, math and technology teachers will place four individuals in Congressional offices and DOE, as directed by legislation.
- In FY 1999, SC piloted its DOE Institute of Biotechnology, Environmental Science, and Computing for Community Colleges. In the summer of 1999, 125 community college students attended an eight-week scientific research experience at five DOE multipurpose laboratories. Additionally, seven community college faculty members were also selected to work in these DOE laboratories. More than 80 percent of the participating students came from underrepresented groups in math, science, engineering, and technology and many were "non-traditional" students.

Field Operations

- The contract with Stanford University was renewed. The incumbent of this contract is responsible for managing the Stanford Linear Accelerator Center along with the Stanford Synchrotron Research Laboratory. This new performance-based contract is valued at $10,000,000 through FY 2003.
- As a result of project management activities at Chicago, the first shipment of Tritium Producing Burnable Absorber Rods to Tennessee Valley Authority (TVA) reactors will be completed on the commercial light water reactor production of tritium project.
- Negotiations have been completed with TVA to provide reactors to irradiate Tritium Producing Burnable Absorber Rods to guarantee the U.S. a supply of tritium for weapons use.
- The Human Genome Production Sequencing Facility in Walnut Creek, California, was dedicated and is operational. This facility will house a team of scientists from Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and Los Alamos National Laboratory that are working on the

Human Genome Sequencing Project.

- A multi-year contract with Boeing North American Company, valued at $148,500,000, was signed to complete the restoration and remediation of DOE's former Energy Technology Engineering Center in Southern California.
- The contract for the Oak Ridge National Laboratory was awarded to University of Tennessee - Battelle, Limited Liability Company.

Funding Profile

(dollars in thousands)

	FY 1999 Current Appropriation	FY 2000 Original Appropriation	FY 2000 Adjustments	FY 2000 Current Appropriation	FY 2001 Request
Science Program Direction					
Program Direction	44,953	47,860	0	47,860	51,438[a]
Science Education	4,500	4,500	0	4,500	6,500
Field Operations	0[b]	78,748	0	78,748	83,307
Total, Science Program Direction	49,453	131,108	0	131,108	141,245
Staffing (FTEs)					
Headquarters (FTEs)	264	274	0	274	284
Field (FTEs)	49	51	0	51	62
Field Operations (FTEs)	0	767	0	767	732
Total, FTEs	313	1,092	0	1,092	1,078

Public Law Authorization:

Public Law 95-91, "Department of Energy Organization Act"

Public Law 103-62, "Government Performance Results Act of 1993"

[a] Includes $631,000 in FY 2001 for Waste Management activities at Chicago and Oakland Operations Offices that was previously budgeted in FY 1999 and FY 2000 by the Environmental Management program.

[b] Appropriated in Energy Supply Research and Development and managed by the Office of Field Integration in FY 1999.

Funding by Site

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Chicago Operations Office					
Argonne National Laboratory	797	200	900	+700	+350.0%
Brookhaven National Laboratory	398	250	600	+350	+140.0%
Princeton Plasma Physics Laboratory	0	0	250	+250	+100.0%
Chicago Operations Office	3,948	29,226	30,577	+1,351	+4.6%
Total, Chicago Operations Office	5,143	29,676	32,327	+2,651	+8.9%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	309	225	500	+275	+122.2%
Stanford Linear Accelerator Center	15	0	150	+150	+100.0%
Oakland Operations Office	957	21,399	23,761	+2,362	+11.0%
Total, Oakland Operations Office	1,281	21,624	24,411	+2,787	+12.9%
Oak Ridge Operations Office					
Oak Ridge Institute For Science & Education	1,495	725	1,700	+975	+134.5%
Oak Ridge National Laboratory	439	320	800	+480	+150.0%
Thomas Jefferson National Accelerator Facility	0	0	150	+150	+100.0%
Oak Ridge Operations Office	792	34,525	36,625	+2,100	+6.1%
Total, Oak Ridge Operations Office	2,726	35,570	39,275	+3,705	+10.4%
Richland Operations Office					
Pacific Northwest National Laboratory	572	275	750	+475	+172.7%
Washington Headquarters	39,731	43,963	44,482	+519	+1.2%
Total, Science Program Direction	49,453	131,108	141,245[a]	+10,137	+7.7%

[a] Includes $631,000 in FY 2001 for Waste Management activities at Chicago and Oakland Operations Offices that was previously budgeted in FY 1999 and FY 2000 by the Environmental Management program.

Site Description

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a multi-program laboratory located on a 1,700-acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry.

Brookhaven National Laboratory

Brookhaven National Laboratory is a multi-program laboratory located on a 5,200-acre site in Upton, New York. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry.

Chicago Operations Office

Chicago is responsible for the integrated management of its five performance-based contractor laboratory sites--Argonne National Laboratory, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Princeton Plasma Physics Laboratory, and Ames Laboratory; and two government-owned and government-operated federal laboratories--Environmental Measurements Laboratory and New Brunswick Laboratory. Chicago has oversight responsibility for more than 10,000 contractor employees located at various site offices across the Nation. This responsibility includes ensuring the security and environmental safety of the taxpayer's investment--approximately 16,000 acres of land with a physical plant worth of about $5.8 billion. Chicago is often noted as a leader in both intellectual property matters and managing more than 2,000 active procurement instruments. Several departmental elements rely on these patent services and the expertise within this Center of Excellence for Acquisitions and Assistance.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a multi-program laboratory located in Berkeley, California. The laboratory is on a 200-acre site adjacent to the Berkeley campus of the University of California. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry.

Oakland Operations Office

Oakland is responsible for supporting the national securities and science, physics and biomedical research, and high energy physics activities which contribute to the California economy. These activities are conducted mostly at the following major laboratories for which Oakland has oversight responsibility: Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory, and Stanford Linear Accelerator Center. Oakland administers more than 1,600 contracts, grants and assistance awards valued at about $28 billion. Oakland Operations Office manages $1.2 billion in major industrial contracts with Westinghouse, General Electric, and General Atomics and Combustion Engineering. As a Grants Center of Excellence, Oakland administers all grants west of the Mississippi.

Oak Ridge National Laboratory

Oak Ridge National Laboratory is a multi-program laboratory located on a 24,000-acre site in Oak Ridge, Tennessee. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry.

Oak Ridge Operations Office

Oak Ridge has oversight responsibility for the Oak Ridge National Laboratory (ORNL), the East Tennessee Technology Park (ETTP), Paducah Gaseous Diffusion Plant, Portsmouth Gaseous Diffusion Plant, Y-12 Plant, and the government owned and operated Oak Ridge Institute of Science and Education. Oak Ridge has oversight responsibility for more than 15,000 contractor employees located at these sites, as well as responsibility for over 43,000 acres of land and approximately 46,000,000 square feet of facility space, valued at over $12 billion. ORNL has responsibility for the Spallation Neutron Source (construction began in FY 2000). The Y-12 Plant has recently resumed weapons production operations, and the ETTP is responsible for utilizing DOE assets by recycling metals, the sale of precious metals, and the disposition of uranium. Other major initiatives at Oak Ridge include reducing environmental risk; reducing the Y-12 weapons footprint; re-industrializing the ETTP and some parts of the Y-12 Plant for commercial use; the revitalization of the scientific infrastructure; and creating public and private partnerships for regional economic development. Oak Ridge is also recognized as one of the Department's three Financial Centers of Excellence.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on a 150-acre site in Oak Ridge, Tennessee. ORISE conducts research into modeling radiation dosages for novel clinical, diagnostic, and therapeutic procedures. In addition, ORISE coordinates several research fellowship programs and the peer review of all Basic Energy Research funded science.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory is a multi-program laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry.

Princeton Plasma Physics Laboratory

Princeton Plasma Physics Laboratory is a program-dedicated laboratory (Fusion Energy Sciences) located on 72 acres in Princeton, New Jersey. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry.

Thomas Jefferson National Accelerator Facility

Thomas Jefferson National Accelerator Facility is a program-dedicated laboratory (Nuclear Physics) located on 273 acres in Newport News, Virginia. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and science teacher participants on state-of-the-art equipment while engaging them on important issues at the forefront of scientific inquiry.

Program Direction

Mission Supporting Goals and Objectives

Program Direction provides the Federal staffing resources and associated costs required for overall direction and execution of SC program and advisory responsibilities. Program Direction supports staff in the High Energy Physics, Nuclear Physics, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, Computational and Technology Research, Multiprogram Energy Laboratories-Facilities Support, and Energy Research Analyses programs, including management and technical support staff. The staff includes scientific and technical personnel as well as program support personnel in the areas of budget and finance; general administration; grants and contracts; information resource management; policy review and coordination; infrastructure management; construction management; safeguards and security; and environment, safety and health. This program also provides program-specific staffing resources at the Chicago, Oakland, and Oak Ridge Operations Offices directly involved in executing SC programs.

Program Direction also includes resources to cover the costs of centrally provided goods and services procured through the Working Capital Fund at Headquarters, such as supplies, rent, telecommunications, desktop infrastructure, etc.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	3,054	3,345	3,800	+455	+13.6%
Travel	187	190	212	+22	+11.6%
Support Services	198	160	160	0	0.0%
Other Related Expenses	124	166	180	+14	+8.4%
Total, Chicago Operations Office	3,563	3,861	4,352	+491	+12.7%
Full-Time Equivalents	32	32	37	+5	+15.6%
Oakland Operations Office					
Salaries and Benefits	867	889	988	+99	+11.1%
Travel	51	51	47	-4	-7.8%
Support Services	0	0	0	0	0.0%
Other Related Expenses	39	39	55	+16	+41.0%
Total, Oakland Operations Office	957	979	1,090	+111	+11.3%
Full-Time Equivalents	10	10	11	+1	+10.0%

(dollars in thousands, whole FTEs)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Oak Ridge Operations Office					
Salaries and Benefits	634	833	1,498	+665	+79.8%
Travel	40	70	82	+12	+17.1%
Support Services	0	52	56	+4	+7.7%
Other Related Expenses	68	117	178	+61	+52.1%
Total, Oak Ridge Operations Office	742	1,072	1,814	+742	+69.2%
Full-Time Equivalents	7	9	14	+5	+55.6%
Headquarters					
Salaries and Benefits	28,409	30,180	33,349	+3,169	+10.5%
Travel	1,240	1,420	1,359	-61	-4.3%
Support Services	5,146	5,120	4,887	-233	-4.6%
Other Related Expenses	4,896	5,228	4,587	-641	-12.3%
Total, Headquarters	39,691	41,948	44,182	+2,234	+5.3%
Full-Time Equivalents	264	274	284	+10	+3.6%
Total Science					
Salaries and Benefits	32,964	35,247	39,635	+4,388	+12.4%
Travel	1,518	1,731	1,700	-31	-1.8%
Support Services	5,344	5,332	5,103	-229	-4.3%
Other Related Expenses	5,127	5,550	5,000	-550	-9.9%
Total, Science Program Direction	44,953	47,860	51,438	+3,578	+7.5%
Total, Full -Time Equivalents	313	325	346	+21	+6.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Salaries and Benefits			
SC monitors and evaluates over 3,500 grants and contracts at more than 225 institutions, including universities, industry and other government agencies and programs at 13 national and single-purpose laboratories. In FY 2001, SC will support the Re-engineering Waste Management transfers at management and operating contractor facilities administered by the Chicago and Oakland Operations Offices and the management structure of the Spallation Neutron Source Project. Also in FY 2001, SC will support the Scientific and Technical Workforce Retention and Recruitment effort. The Department of Energy has conducted detailed workforce analyses that have identified current and projected staffing shortfalls, especially among the scientific and technical disciplines. During 1999, DOE conducted a systematic analysis of critical staffing needs within the context of current and projected Research & Development (R&D) program missions. The Department will focus on building and sustaining a talented and diverse workforce of R&D Technical Managers. This will include innovative recruitment strategies, retention incentives, comprehensive training and development programs for new and current employees, and succession planning. The FY 2001 program direction request for SC includes $1,186,000 in salaries and benefits for this effort. This will enable the recruitment of experienced scientists and related support staff (10 full-time equivalents) in areas of emerging interest to the Department's science mission. Funds will also be used to motivate and retain highly skilled, top-performing technical managers with, for example, retention allowances and performance awards...........	32,964	35,247	39,635

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Travel			
Travel includes all costs of transportation of persons, subsistence of travelers, and incidental travel expenses in accordance with Federal travel regulations. Travel also includes transportation costs for new hires and Federal transferees in support of Scientific and Technical Workforce Retention and Recruitment efforts. Alternatives to travel such as teleconferencing will continue to be utilized when possible.	1,518	1,731	1,700
Support Services			
Provides the minimum level of support services needed for mailroom operations; travel management; environment, safety and health support; safeguards and security; computer systems development; and hardware and software installation, configuration, and maintenance activities. As a Lead Program Secretarial Office, the capability to develop/implement integrated business management systems and the related information technology infrastructure is required in order to strengthen collaborative efforts between Headquarters and field components.	5,344	5,332	5,103
Other Related Expenses			
Provides funds to enhance the technical and professional capability of the Federal staff, acquire computer hardware and software necessary to accomplish corporate systems development and networking upgrades, and provide $3,506,000 for Working Capital Fund assessments. Funding in support of the Scientific and Technical Workforce Retention and Recruitment effort in areas crucial for effective job performance is also included.	5,127	5,550	5,000
Total, Program Direction..	44,953	47,860	51,438

Explanation of Funding Changes From FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Salaries and Benefits	
▪ The increase includes cost of living, locality pay, within grades, promotions, and awards; 5 FTEs at Oak Ridge Operations Office to complete the management structure of the Spallation Neutron Source Project Office; 5 FTEs at Chicago and 1 FTE at Oakland Operations Offices to support the Waste Management transfers; and 10 FTEs in support of the Scientific and Technical Workforce Retention and Recruitment effort.	+4,388
Travel	
▪ The decrease reflects a continuing effort to reduce travel costs...	-31
Support Services	
▪ The decrease represents efficiencies achieved in information technology............................	-229
Other Related Expenses	
▪ The decrease represents a reduction (-$712,000) in maintenance costs associated with information management activities, offset by an increase in the Working Capital Fund (+$162,000)..	-550
Total Funding Change, Program Direction..	+3,578

Support Services

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Technical Support Services					
Economic and Environmental Analysis	1,488	1,325	1,325	0	0.0%
Test and Evaluation Studies	160	100	100	0	0.0%
Total, Technical Support Services	1,648	1,425	1,425	0	0.0%
Management Support Services					
Management Studies	207	110	110	0	0.0%
Training and Education	63	40	40	0	0.0%
ADP Support	2,376	2,847	2,618	-229	-8.0%
Administrative Support	1,050	910	910	0	0.0%
Total, Management Support Services	3,696	3,907	3,678	-229	-5.9%
Total, Support Services	5,344	5,332	5,103	-229	-4.3%

Other Related Expenses

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Training	68	74	74	0	0.0%
Working Capital Fund	3,000	3,344	3,506	+162	+4.8%
Printing and Reproduction	33	11	0	-11	-100.0%
Rental Space	26	0	0	0	0.0%
Software Procurement/Maintenance Activities/Capital Acquisitions	2,000	2,115	1,420	-695	-32.9%
Other	0	6	0	-6	-100.0%
Total, Other Related Expenses	5,127	5,550	5,000	-550	-9.9%

Science Education

Mission Supporting Goals and Objectives

For over 50 years, the Department of Energy and its predecessor agencies have supported science and engineering education programs involving university faculty as well as pre-college teachers and students. The Department has provided support for university students, pre-college teachers and college faculty through hands-on research experiences at the Department's national laboratories and research facilities.

The involvement of DOE's national laboratories in faculty/student research is perhaps the most distinguishing feature of the agency's participation over the years in science and engineering education. No other Federal agency has the extensive network of research laboratories and facilities as DOE with its unique physical and human resources. These laboratories and facilities have been the key to the Department's contribution over time to the Nation's science and engineering education goals.

As we approach the new century, the Nation continues to face important challenges related to recruiting and retaining students who have historically been under-represented (e.g., women, disabled persons, African Americans, Hispanic Americans and Native Americans) in science and engineering fields. Guided by recent reports such as the National Research Council on Undergraduate Education Achievement Trends in Science and Engineering, SC will continue to design an undergraduate research fellowship program that couples academic study with extensive hands-on research experiences in a variety of DOE national laboratory settings. This program is intended to enhance the likelihood that under-represented students will successfully complete their undergraduate studies and move on to graduate school. Historically, over two-thirds of undergraduates who have participated in DOE programs such as this have gone on to graduate school in disciplines directly relevant to the DOE science and technology missions.

Funding Schedule

(dollars in thousands)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Energy Research Undergraduate Laboratory Fellowships	3,215	3,160	3,700	+540	+17.1%
National Science Bowl Program	400	400	400	0	0.0%
Albert Einstein Distinguished Educator Fellowship Program	385	440	400	-40	-9.1%
DOE Institute of Biotechnology, Environmental Science, and Computing for Community Colleges	500	500	2,000	+1,500	+300.0%
Total, Science Education	4,500	4,500	6,500	+2,000	+44.4%

Detailed Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Energy Research Undergraduate Laboratory Fellowships			
The Energy Research Undergraduate Laboratory Fellowship Program is a key component of Science Education. The program enables students to focus their research interests on solving current scientific problems and prepare for meeting the challenge of DOE's future energy science mission requirements. This program provides undergraduates real hands-on experiences at the national laboratories and facilities. The program will ensure a steady flow of students with technical expertise into the Nation's pipeline of workers in both academia and industry.	3,215	3,160	3,700
National Science Bowl Program			
SC will manage and support the National Science Bowl for high school students from across the country. Since its inception, more than 60,000 high school students have participated in this event. The National Science Bowl is a highly publicized academic competition among teams of high school students who answer questions on scientific topics in astronomy, biology, chemistry, mathematics, physics, earth, computer, and general science. In 1991, DOE developed the National Science Bowl to encourage high school students from across the Nation to excel in math and science and to pursue careers in those fields. It provides the students and teachers a forum to receive national recognition for their talent and hard work. DOE plans to invest $400,000 in the National Science Bowl to manage both regional and national competitions.	400	400	400
Albert Einstein Distinguished Educator Fellowship Program			
The Albert Einstein Fellowship Awards for pre-college science, math and technology teachers continues to be a strong pillar of the program for bringing real classroom experiences to our education programs and outreach activities. This Congressional initiative, established by the Albert Einstein Distinguished Educator Fellowship Act of			

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
1994, has enabled the Department to maintain an enriching relationship with the National Triangle Coalition that serves the Federal Government as the clearinghouse for selecting the teachers. DOE plans to invest $400,000 in the Einstein Fellowship Awards that will allow us to place teachers at the Department and in the U.S. Congress....................................	385	440	400
DOE Institute of Biotechnology, Environmental Science, and Computing for Community Colleges			
The DOE Institute of Biotechnology, Environmental Science, and Computing for Community Colleges is a collaborative effort between DOE and five of its multiprogram laboratories with the American Association of Community Colleges and specified member institutions. This program is designed to address shortages, particularly at the technician and paraprofessional levels, in the rapidly expanding areas of biotechnology, environmental science, and computing, that will help develop the human resources needed to continue building the Nation's capacity in these critical areas for the next century. The Institute provides a 10-week research fellowship for highly qualified community college students at a DOE national laboratory. Students are mentored by world-renowned scientists, learn scientific inquiry and methodology to solve complex scientific problems, are introduced to and learn to use the latest scientific instruments, and learn about career options in the science and technology enterprise. To be eligible, students must: (1) be enrolled in at least six hours of coursework at the time of application; (2) be interested in a career in the fields of biotechnology, environmental science, or computing; (3) have completed at least 12 hours of community college credits that count toward a degree with at least six hours in science mathematics, engineering, or technology courses; (4) have a minimum undergraduate grade point average of 3.25 on a 4.0 scale; (5) be a citizen of the United States or a Permanent Resident Alien; and (6) be at least 18 years of age by June 1 of the year of the appointment. Students apply through an on-line application process..	500	500	2,000
	4,500	4,500	6,500

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Total, Science Education..			

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Energy Research Undergraduate Laboratory Fellowship Program	
▪ Increase the number of students for fall and spring research appointments.......................	+540
Albert Einstein Fellowship	
▪ One fellowship recipient was given an additional time extension in FY 2000.	-40
DOE Institute of Biotechnology, Environmental Science, and Computing for Community Colleges	
▪ Expanding the Community College program from a pilot to a full competitive program. ...	+1,500
Total Funding Changes, Science Education..	+2,000

Field Operations

Mission Supporting Goals and Objectives

The Field Operations subprogram pays the salaries and benefits of the Federal personnel located at the Chicago, Oakland, and Oak Ridge Operations Offices. The staff is responsible for managing the daily business, administrative and technical services that support Science and other DOE program-specific scientific and technical work within the field and laboratory structure. The following administrative and technical services are provided by this core matrix staff: financial stewardship, personnel management, contract and procurement acquisition, labor relations, legal counsel, public and congressional liaison, intellectual property and patent management, environmental compliance, safety and health management, infrastructure operations maintenance, information systems development and support, and reindustrialization.

In addition, this subprogram provides funding for the fixed requirements associated with rent, utilities, and telecommunications. Other requirements such as information systems support, administrative support, mail services, printing and reproduction, travel, certification training, vehicle acquisition and maintenance, equipment, classified/unclassified data handling, records management, health care services, guard services, and facility and ground maintenance are also included. These infrastructure requirements are relatively fixed. The offices are also responsible for supplying office space and materials for the Office of Inspector General located at each site. With the budget reductions over the immediate past years, these areas are already funded at the minimum level necessary to support the Department's critical missions in the field.

Other operational requirements funded include occasional contractor support to perform ecological surveys, cost validations, and environmental assessments; ensure compliance with Defense Nuclear Safety Board safety initiatives; abide by site preservation laws and regulations; and perform procurement contract closeout activities. Departmental and programmatic initiatives as well as regional and congressional constituents influence these requirements.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 1999	FY 2000	FY 2001	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	0	20,021	19,958	-63	-0.3%
Travel	0	350	396	+46	+13.1%
Support Services	0	1,500	1,829	+329	+21.9%
Other Related Expenses	0	3,054	3,642	+588	+19.3%
Total, Chicago Operations Office	0	24,925	25,825	+900	+3.6%
Full-Time Equivalents	0	253	236	-17	-6.7%
Oakland Operations Office					
Salaries and Benefits	0	14,994	15,370	+376	+2.5%
Travel	0	250	259	+9	+3.6%
Support Services	0	2,092	2,831	+739	+35.3%
Other Related Expenses	0	3,084	4,211	+1,127	+36.5%
Total, Oakland Operations Office	0	20,420	22,671	+2,251	+11.0%
Full-Time Equivalents	0	178	171	-7	-3.9%
Oak Ridge Operations Office					
Salaries and Benefits	0	26,435	27,518	+1,083	+4.1%
Travel	0	400	345	-55	-13.8%
Support Services	0	3,026	2,745	-281	-9.3%
Other Related Expenses	0	3,542	4,203	+661	+18.7%
Total, Oak Ridge Operations Office	0	33,403	34,811	+1,408	+4.2%
Full-Time Equivalents	0	336	325	-11	-3.3%
Total Field Operations					
Salaries and Benefits	0	61,450	62,846	+1,396	+2.3%
Travel	0	1,000	1,000	0	0.0%
Support Services	0	6,618	7,405	+787	+11.9%
Other Related Expenses	0	9,680	12,056	+2,376	+24.5%
Total, Field Operations	0[a]	78,748	83,307	+4,559	+5.8%
Full-Time Equivalents	0	767	732	-35	-4.6%

[a] Appropriated in Energy Supply Research and Development and managed by the Office of Field Integration in FY 1999.

Detail Program Justification

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Salaries and Benefits			
▪ Funds the management and administrative staff that complement the multiple program-specific efforts performed within the field and laboratory structure under the auspices of three multi-program Operations Offices (Chicago, Oakland, and Oak Ridge). The FY 2001 budget request supports 732 full-time equivalents. From FY 2000 to the FY 2001 request, the full-time equivalents have been reduced by 4.6 percent. With such a reduction, in FY 2001, the staff will be devoted to re-engineering business processes, developing process improvements, and investing in information technology.	0	61,450	62,846
Travel			
▪ Enables field staff to participate on task teams, work various issues, conduct compliance reviews, and perform contractor oversight to ensure implementation of DOE orders and regulatory requirements at the facilities under their purview. Also provides for attendance at conferences and training classes, and permanent change of station relocation, etc.	0	1,000	1,000
Support Services			
▪ Provides centralized information management systems and administrative support at each office. For FY 2001, the field will need to make information technology infrastructure investments that will build on the integrated business management systems and support re-engineered processes and process improvements. These requirements are in addition to the routine computer programming, local area network connectivity, computer desktop maintenance, communications centers, and audio/TeleVideo support. A variety of other support services are also fundamental requirements at each office, which include mail distribution, travel management, contract closeout, remote site office support, copy and distribution centers, trash removal, and facility and grounds maintenance, etc..	0	6,618	7,405

	(dollars in thousands)		
	FY 1999	FY 2000	FY 2001
Other Related Expenses			
Provides funds necessary for day-to-day requirements associated with operating a viable office. Within this category, $8,000,000 funds the fixed requirements associated with rent, utilities, and telecommunications. More than half of the $8,000,000 is associated with office space occupied within Federal buildings and the rent paid to the General Services Administration. Eliminating the amount of space occupied has moderately reduced the rent expense. The remaining $4,056,000 supports information technology infrastructure investments ($1,400,000) and other day-to-day expenses ($2,656,000), including postage, printing and reproduction, computer hardware and software, copier leases, and in most cases the site-wide health care service and vehicle fleet maintenance. Employee training and development and the supplies and furnishings used by the Federal staff are also included	0	9,680	12,056
Total, Field Operations	0	78,748	83,307

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2001 vs. FY 2000 ($000)
Salaries and Benefits	
▪ This increase is the net effect of changes in the staffing level from FY 2000 to FY 2001. The funding change represents a decrease in related costs associated with early retirements needed in FY 2000 to make significant reductions in the Federal staffing level. In addition, the savings, related to the 4.6 percent reduction in full- time equivalents from FY 2000 to FY 2001, support a decrease in the funding request. These decreases are offset by an allowance for general pay and locality raises, promotions, and within grades in FY 2001	+1,396
Travel	
▪ Travel remains the same as the prior year as this level supports increasing oversight responsibilities	0
Support Services	
▪ The increase will support obtaining expertise that will facilitate process improvements, develop state-of-the-art automation tools, and build on existing integrated business management systems among three field offices. Under the Department's new management structure, SC and the three Operations Offices are collaborating in a corporate, integrated approach to business systems, utilizing strategic information planning and information architecture	+787
Other Related Expenses	
▪ The increase is attributable to inflationary adjustments associated with essential day-to-day operations (+$894,000), adequate funding for employee training and development (+$382,000), and information technology investments and architecture (+$1,100,000).	+2,376
Total Funding Change, Field Operations	+4,559

Support Services

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Technical Support Services					
Feasibility of Design Consideration	0	0	0	0	0.0%
Test and Evaluation Studies	0	0	0	0	0.0%
Economic and Environmental Analysis	0	396	396	0	0.0%
Total, Technical Support Services	0	396	396	0	0.0%
Management Support Services					
Administrative	0	1,682	2,100	+418	+24.9%
ADP Support	0	4,540	4,909	+369	+8.1%
Total Management Support Services	0	6,222	7,009	+787	+12.6%
Total, Support Services	0	6,618	7,405	+787	+11.9%

Other Related Expenses

	(dollars in thousands)				
	FY 1999	FY 2000	FY 2001	$ Change	% Change
Training	0	382	764	+382	+100.0%
Printing and Reproduction	0	398	550	+152	+38.2%
Rent & Utilities & Telecommunication	0	7,600	8,000	+400	+5.3%
Information Technology	0	300	1,400	+1,100	+366.7%
Other	0	1,000	1,342	+342	+34.2%
Total, Other Related Expenses	0	9,680	12,056	+2,376	+24.5%