Science

Proposed Appropriation Language

For expenses of the Department of Energy activities including the purchase, construction and acquisition of plant and capital equipment and other expenses necessary for science activities in carrying out the purposes of the Department of Energy Organization Act (42 U.S.C. 7101 et seq.), including the acquisition or condemnation of any real property or facility or for plant or facility acquisition, construction, or expansion, and purchase of not to exceed [5] *6* passenger motor vehicles for replacement only, [$2,682,860,000] *$2,835,393,000*, to remain available until expended[: *Provided*, That $7,600,000 of the unobligated balances originally available for Superconducting Super Collider termination activities shall be made available for other activities under this heading]. *(Energy and Water Development Appropriations Act, 1999.)*

[An additional amount of $15,000,000, to remain available until expended, for Department of Energy—Energy Programs, "Science", is hereby appropriated.] *(Omnibus Consolidated and Emergency Supplemental Appropriations Act, 1999, Public Law 105-277, Division A, Section 109.)*

Office of Science

Executive Budget Summary

The Office of Science (SC) requests $2,844 Million for Fiscal Year 2000, an increase of $138M over FY 1999, to invest in thousands of individual research projects at hundreds of research facilities across the U.S., primarily in our national laboratories and research universities. The FY 2000 request will allow for continued construction of the Spallation Neutron Source, the first world class neutron source built by the U.S. in over 30 years; a new Scientific Simulation Initiative that will revolutionize our ability to solve scientific problems of extraordinary complexity and enable us to apply these new resources toward advancing DOE missions; participation in the Next Generation Internet effort with a focus on R&D and implementation of the technologies and tools that help meet mission requirements and contribute to the Scientific Simulation Initiative.

A History of Success:

Past successes from the SC research program and scientific user facilities have produced a rich history of contributions to science and society.

- Supported the work of 66 Nobel Laureates, from Enrico Fermi and E.O. Lawrence to Richard Smalley and Paul Boyer.
- SC's High Energy Physics program Supported *Science Magazine's* "1998 Breakthrough of the Year - *The Accelerating Universe*"

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- Developed the original prototype for positron emission tomography (PET) and the most widely used radio-pharmaceuticals used in nuclear medicine, provided the knowledge base for the nation's, and world's, radiation exposure standards, established the first Human Genome Program and the first global climate change research program.
- Advanced our understanding of the subatomic world and the fundamental forces and particles of nature through forefront research and research facilities, including the world's first super-conducting accelerator. These facilities offer a window into the most elusive particles and interactions at the very heart of matter illuminating the origin of the universe.
- Building on the advances of accelerator physics, synchrotron light sources were first conceived, constructed and utilized by SC scientists for research that enabled the discovery of new materials, advanced chip technologies, and breakthroughs in structural biology.
- Provided the first scientific investigation of multi-megawatts of fusion power produced in laboratory plasmas.

A Notable Change:

During FY 1999 budget deliberations, in recognition of more than 50 years of contributions to science and basic research, Congress changed the name of the Office of Energy Research to the Office of Science. With the FY 2000 budget request, we begin a new era as the Office of Science and, looking ahead to the challenges and opportunities of the twenty-first century, we are building a new SC strategic plan for the future research needs of the Department.

Our Mission Hasn’t Changed:

Our mission remains to: produce the scientific and technical knowledge needed to develop energy technology options; understand the health and environmental implications of energy production and use; maintain U.S. leadership in understanding the fundamental nature of energy and matter; provide and operate the large-scale facilities required in the natural sciences; ensure U.S. leadership in the search for scientific knowledge; and support the availability of scientific talent for the next generation.

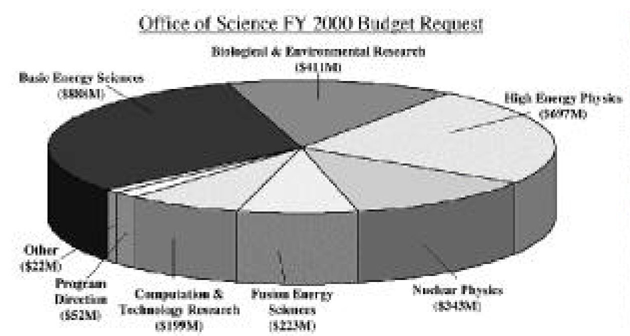

Figure 1

The FY 2000 budget request, depicted in Figure 1 and Table 1, has a program structure, that meets our mission consistent with Department goals and strategies. The major programs of the Office of Science are: High Energy and Nuclear Physics, Basic Energy Sciences, Biological and Environmental Research, Computational and Technology Research, and Fusion Energy Sciences.

The Department of Energy is a science agency because its mission and goals require technologies and scientific knowledge far beyond that which is currently available. From safeguarding the nuclear stockpile to ensuring our nation’s energy supply for the next century, DOE continues to challenge the frontiers of science and technology.

The DOE Strategic Plan outlines the vision, goals and strategic objectives that will, through leadership in science and technology, help the DOE to meet those challenges. In keeping with the Government Performance and Results Act (GPRA), the Office of Science FY 2000 budget request includes program specific goals, strategies, and measures that focus our research activities and ensure continuity with Departmental plans and national goals.

Rethinking Our Goals and Strategies:

In the past year, the Department has begun to characterize the whole of our R&D efforts across business lines. The purpose and scope of this effort are to extend the work of the new SC strategic plan in terms of the R&D investments that enable us to meet our objectives and goals, and to assemble key information for improving our analysis and management of these investments.

The Office of Science’s basic research supports and enables the R&D of the other business lines. A Science Portfolio has been developed with this fact in mind so as to clarify and improve integration of our program results throughout the Department. This Portfolio accompanies the release of the FY 2000 budget request.

As the Department builds R&D portfolios for its other business lines, the Office of Science will continue to integrate basic research with the applied R&D in the other business lines’ portfolios so that there are strong linkages between technology needs and science.

The revised Strategic Plan of the Office of Science, to be published in Spring 1999, will articulate the long-range vision, goals, strategies, and objectives for our programs. The Science Portfolio complements and supports the strategic plan by providing a near-term “snapshot” of our investments against the new strategic framework.

The motivations behind this planning effort are to develop a shared long-term focus for SC programs, their scientific communities and performers; to position our future scientific program content to better serve the other DOE business lines and provide a framework for cooperation and risk taking; to project future possibilities and directions for our programs based on the latest technologies and scientific advances; to better illustrate the unique and coordinated role of SC programs within the DOE mission and the federal science investment; to inspire our researchers and to better communicate our program content and successes to our sponsors and the general public.

The new SC strategic plan, and supporting Science Portfolio, is structured around five high-level goals with twelve strategic objectives, listed in Figure 2. These goals were developed through a series of planning activities and workshops that drew on the experience and knowledge of our research scientists and stakeholders to capture both what is necessary and what is possible for our science as we look to the next century.

The first goal, **Fueling the Future**, is centered on science for affordable and clean energy options for the future. Some of the questions that motivate this goal are: *How can we tap and harness affordable, clean fuels? What clean new electric power systems will fuel the future?* and *How can energy systems be made more efficient and environmentally sound?* Development of this goal has been closely connected with the development of the Energy R&D portfolio and the objectives directly map onto the energy portfolio.

The second goal, **Protecting our Living Planet**, is centered on understanding energy impacts on people and the biosphere. Some of the questions that motivate this theme are: *What are the sources and fate of energy-related by-products? What factors affect global climate and how can they be controlled?* and *How do complex biological and environmental systems respond to our energy use?* This goal also contributes to both the Energy R&D portfolio and the Environmental R&D portfolio.

- **Fueling the Future**
  - **New Fuels**
  - **Clean and Affordable Power**
  - **Efficient Energy Use**
- **Protecting Our Living Planet**
  - **Sources and Fate of Energy By-Products**
  - **Impacts on People and the Environment**
  - **Prevention and Protection**
- **Exploring Energy and Matter**
  - **Components of Matter**
  - **Origin and Fate of the Universe**
  - **Complex Systems**
- **Extraordinary Tools for Extraordinary Science**
  - **Instrumentation for the Frontiers of Science**
  - **Scientific Simulation**
  - **Institutional Capacity**
- **Enabling World Class Science**

Figure 2

The third goal, **Exploring Energy and Matter**, is centered on discovering the building blocks of atoms and life. Some of the questions that motivate this theme are: *What are the fundamental components of matter? How can the origin and fate of the Universe reveal the secrets of energy, matter and life?* and *How do atoms and molecules combine to form complex dynamic systems?* This goal captures the most fundamental research in the Office of Science. The complex systems question links to R&D efforts in all of the DOE business lines.

The fourth goal, **Extraordinary Tools for Extraordinary Science**, is centered on the national assets that DOE provides for forefront, multidisciplinary research. This goal builds on the unique role of the Office of Science in providing the nation with forefront research facilities such as the National Laboratories, and an array of research accelerators, reactors and other unique facilities. The Office of Science will continue to ensure that these critical research tools remain accessible to peer reviewed researchers from all across the nation and meet the technical challenges of forefront scientific investigation. This goal looks to the future and to training and educating the next generation of scientists and engineers.

Some of the questions that motivate this goal are: *How can we explore the frontiers of the natural sciences? How can we predict the behavior of complex systems?* and *How can we strengthen the nation's capacity for multidisciplinary science?* This goal enables research in all of the DOE business lines. By organizing future facilities needs, as identified by the scientific community, this theme ensures that America's research capability will remain both accessible and state of the art.

The fifth goal, **Enabling World Class Science**, conveys the commitment of DOE and National Laboratory staff to continuously improve their operational processes. Of paramount importance is the selection and conduct of excellent, productive science that is carried out safely and with care for the environment and involvement of local communities.

Implementing the New Strategies - Initiatives for FY 2000:

These five goals provide a framework for current programs and a platform for future efforts. FY 2000 initiatives and priorities are detailed below. Figure 3 lists these initiatives and identifies linkages to the SC goals.

Scientific Simulation Initiative - It is now possible to obtain computational capabilities 100 times faster than currently in common use through the application of technologies developed for the Accelerated Strategic Computing Initiative (ASCI). Therefore the Department of Energy, in coordination with the National Science Foundation and other federal science programs, has developed a Scientific Simulation Initiative

	Fuel the Future	Protect Our Living Planet	Explore Energy & Matter	Extraordinary Tools for Extraordinary Science
Scientific Simulation Initiative	✓	✓	✓	✓
Spallation Neutron Source	✓			✓
Large Hadron Collider			✓	✓
Scientific User Facilities	✓	✓	✓	✓
Next Generation Internet				✓
Climate Change Technology Initiative	✓	✓		
Genome	✓	✓	✓	✓

Figure 3

(SSI) in support of the President's Information Technology Initiative. The mission of the SSI is to further develop and employ the emerging generation of very high performance computers as major tools for scientific inquiry. These resources will revolutionize our approach to solving complex problems in *energy, environment, and fundamental research* and will stimulate our national system of innovation.

Portions of the program will be directed by a joint SC/Defense Programs ASCI research management committee. Within the Office of Science, the SSI will be an integrated effort with the Computational and Technology Research (CTR) program coordinating and overseeing competitive, peer reviewed selections of sites and applications. CTR, with Basic Energy Sciences (BES) and Biological and Environmental Research (BER), will manage the basic research applications.

Combustion - Currently, eighty-five percent of U.S. energy use is derived from the combustion of fossil fuels and this dependence on combustion is not likely to change in the coming decades. Combustion remains one of the primary causes of lowered air quality in urban environments. At present, engineers have neither sufficient knowledge nor the computational tools to understand and predict the chemical outcome of combustion processes with any degree of practical reliability. Existing models that guide the design process are of very limited usefulness because of the extraordinary complexity of the combustion process. With very high end computing resources and a concerted research program in combustion modeling, we can develop the next generation of combustion modeling tools for accelerated design of combustion devices meeting national goals of emission reduction and energy conservation.

Global Systems -Unlike many disciplinary areas of research, the complex workings of the global environmental system cannot be studied in a laboratory setting. The integration of knowledge from the many disciplines that together describe the global system can only be performed in computer simulation models. It is only through such general circulation models that it is possible to understand current climate and climate variability and to predict future climate and climate variability, including prediction of the possible effects of human activities on the global system. Advances in scientific understanding are therefore predicated upon the successful development of modeling tools to keep pace with the rapid advances in the quality and quantity of data available. These tools will lead to the development of detailed fully coupled global system models that accurately reproduce, and ultimately predict, the behavior of the interacting components of the system, i.e. the global atmosphere, the world ocean, the terrestrial land surface and both glacial and sea ice.

Fundamental Research - Whereas the scientific accomplishments of this century have resulted in seeking and understanding the fundamental laws that govern our physical universe, the science of the coming century will be characterized by synthesis of this knowledge into predictive capabilities for understanding and solving a wide range of scientific problems, many with practical consequences. In this endeavor, the computer will be a primary instrument of scientific discovery. Many areas of scientific inquiry, critical to the department's mission, will be advanced dramatically with access to high-end computation - including, but not limited to, materials sciences, structural genomics, high energy and nuclear physics, subsurface flow, and fusion energy research.

The **Spallation Neutron Source** (SNS) - The importance of neutron science for fundamental discoveries and technological development has been enumerated in all of the major materials science studies over the past two decades, including a major study by the National Research Council entitled "Major Facilities for Materials Research and Related Disciplines" (Seitz-Eastman Report)

As the needs of our high-technology society have changed, so has the way in which we conduct the R&D that helps us to meet those needs. It has become increasingly important to develop 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, demanding applications.

The SNS is a next-generation facility for these types of applications. Neutron scattering will play a major role in all forms of materials design and understanding. This research will lead to the development of advances such as: 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; improved understanding of form and function in biological structures and the development of new drugs for medical care.

Upon completion, the SNS will be the world's most powerful neutron source, accommodating more than 1,000 researchers and 30 to 40 special purpose instruments.

The SNS Total Project Cost (TPC) is estimated to be $1,360 million over a 7.25-year schedule. The original TPC of $1,333 million (7-year schedule) was independently validated to within 1%. Throughout the life of the project, semi-annual reviews will track cost and management. FY 1999 funding provided for the start of Title I design activities, initiation of subcontracts and long-lead procurement, and continued R&D to reduce technical and schedule risks. FY 2000 funding of $214M will support Title II (detailed) design for the technical components and control systems. Construction will begin in FY 2000 on some of the conventional facilities as will the procurement of key technical equipment.

The SNS project is an example of DOE's commitment to use the DOE laboratories as a system. Under DOE leadership, Oak Ridge National Laboratory is responsible for the project with participation from Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, Brookhaven National Laboratory, and Argonne National Laboratory. The laboratories have been working together most effectively and R&D is proceeding smoothly.

Scientific Facilities Utilization - This FY 2000 budget request continues to strongly support Scientific Facilities Utilization in the following programs: Basic Energy Sciences, High Energy Physics, Nuclear Physics, Fusion Energy Sciences, Biological and Environmental Research, and Computational and Technology 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, such as the Combustion Research Facility (CRF) at Sandia National Laboratories, Livermore, California. The CRF is an internationally recognized facility for the study of combustion science and technology, which will begin its first year of operation after its Phase II development project.

The user community continues to be pleased with the results of the Science Facilities Initiative as evidenced by their many letters of support and by the positive results of surveys conducted at the facilities

The **Large Hadron Collider** - The foremost high energy physics research facility of the next decade will be the Large Hadron Collider (LHC) at CERN, the European Center for Particle Physics. The primary physics goals of the LHC will impact our understanding of the relation of mass, fundamental forces, and the structure and origin of the universe. U.S. participation in the LHC is required 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.

The LHC is an outstanding example of international cooperation in large scientific projects, as well as interagency and inter-laboratory cooperation. An International Cooperation Agreement has been negotiated between CERN, DOE and NSF. The Agreement provides for U.S. participation in the construction of the accelerator, and of the two very large detectors, ATLAS and CMS. Carefully defined lists of deliverables and costs have been agreed upon for each of these areas of participation. U.S. costs are capped at $531M ($450M DOE and $81M NSF), consistent with Congressional guidance. In return, participating U.S. universities and laboratories will join, as full partners, in LHC experiments. In addition, a Memorandum of Understanding (MOU) has been executed between DOE and NSF that defines the relationship between the agencies relative to programmatic coordination of U.S. LHC activities include joint oversight and execution of the U.S. LHC Construction Program.

Under the terms of this MOU, Fermilab is the Lead Laboratory for the accelerator portion of the program, which it will execute in cooperation with Brookhaven (BNL) and Lawrence Berkeley (LBNL) National Laboratories. BNL is the host laboratory for the ATLAS portion of the program, which also involves Argonne National Laboratory (ANL) and LBNL along with 28 university groups. Similarly, Fermilab is the host laboratory for the CMS detector portion of the program, including BNL and Los Alamos National Laboratory (LANL) along with 33 university groups. Cost and schedule baselines have been reviewed and validated for each of the three programs and management systems are in place to monitor progress against baselines.

The **Next Generation Internet** (NGI) - The program is creating the foundation for more powerful and versatile networks of the 21st century, just as previous federal investments in information technology R&D created the foundation for today's Internet. This program is critical to DOE’s science and technology missions because enhancements to today’s Internet from commercial R&D will not be sufficient to enable effective use of: petabyte/year High Energy and Nuclear Physics facilities such as the Relativistic Heavy Ion Collider (RHIC); to provide remote visualization of terabyte to petabye data sets from computational simulation; to develop advanced collaboratories; and to enable effective remote access to tomorrow's advanced scientific computers.

For example, typical RHIC experimental collaborations involve thousands of scientists at hundreds of institutions across the country and the world. 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. Using NGI it would take 25 hours.

Thus, DOE's NGI research program is focused on discovering, understanding, developing, testing and validating the networking technologies needed to enable wide area, data intensive and collaborative computing. The DOE applications share two important characteristics. They all involve extremely large data sets and they all require that scientists be able to interact with the data in (nearly) real time. Current network technology limitations significantly limit our ability to address these characteristics.

The DOE program includes research in advanced protocols, special operating system services for very high speed, and very advanced network control, the components needed to enable wide area, data intensive and collaborative computing. In addition the DOE program addresses issues that result from the many different kinds of network devices, network-attached devices, and services that need to be integrated together. 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. This type of integration, as well as the issues of improving the performance of the individual components, all require significant research because the issues are currently not well understood. Indeed, the first identification of many of these issues is the result of previous work in collaboratories and visualization supported by DOE.

Thus, DOE's participation in the NGI builds on previous DOE research and its over two decades of success in using advanced networks as tools for science. Furthermore, the differences between the requirements of commercial networks and networks for scientific research require DOE to conduct this research because these tools and technologies will not be developed by commercial R&D. However, the results and “spinoffs” of this research, after testing and prototyping by the scientific community, will impact broad commercial use of networks. DOE’s FY 2000 NGI program will build on the results of the competitive research solicitations conducted in FY 1999.

Climate Change Technology Initiative (CCTI)- Eighty-five percent of our Nation’s energy results from the burning of fossil fuels, a process that adds carbon to the atmosphere. Because of the potential environmental impacts of increases in atmospheric carbon dioxide, carbon management has become an international concern and is a focus of the CCTI.

The Office of Science is well positioned to make significant contributions to the many solutions needed to address this problem. SC can build on the fundamental discoveries of core research programs in carbon and non-carbon energy sources, carbon sequestration, and carbon recycling, extending them to the new discoveries needed to make carbon management practical and efficient.

Activities in both Basic Energy Sciences and Biological and Environmental Research support the DOE and Administration CCTI efforts in: *science for efficient technologies, fundamental science underpinning advances in all low/no carbon energy sources, and sequestration science.*

The SC portion of the CCTI leverages the foundation of excellent research already underway. The additional SC effort will also have a major impact on many scientific disciplines by advancing the state of knowledge in such fields as genome science, molecular, cellular and structural biology, biochemistry, chemical dynamics, solid state chemistry, photochemistry, ecology, nano- and meso-phase materials science, condensed matter physics, engineering, theoretical chemistry and physics.

For example, the BER microbial genome program has made significant investments in the technology that enables genome sequencing at rates previously unattainable. Capitalizing on these investments, the genomes of microbes that produce methane and hydrogen from carbonaceous sources will be sequenced as part of the first awards under CCTI. This will enable identification of key genetic components of the organisms that regulate the production of these gases. The carbon sequestration research program will focus on understanding the natural terrestrial sequestration cycle and the natural oceanic sequestration cycle as part of the first awards under the CCTI. The ultimate goal is to enhance the natural carbon cycle in both the terrestrial and oceanic systems. The search for new fuel sources and carbon sequestration research are key elements of the carbon management program.

CCTI research and related activities within the Office of Science will continue to be coordinated with the Office of Fossil Energy. FY 1999 integration efforts include the coordination of new CCTI proposal solicitations and preparation of a detailed carbon dioxide sequestration roadmap.

Genome - In only its first full year of operation, the DOE Joint Genome Institute (JGI) became the second leading public producer of high quality human DNA among U.S. sequencing centers. The JGI is boldly scaling up its sequencing capacity from 21 million finished bases in FY 1998 to 30 million finished bases and 40 million high quality draft bases in FY 1999. In total, SC will complete sequencing of 50 million finished and 70 million high quality draft subunits of human DNA to submit to publicly accessible databases in FY 2000. In addition, SC will complete the full genetic sequencing of more than 10 microbes that have significant potential for waste cleanup and energy production.

Improvements in high throughput human DNA sequencing technology and sequence data management are needed to complete the first human genome by 2003 and to efficiently and cost effectively use that sequence information for future medical diagnoses and scientific discovery. The Joint Genome Institute, in which the National Laboratories work as a system, are primarily focused on high throughput sequencing. FY 2000 is the third year of a major 3-5 year scale-up in DNA sequencing capability for this virtual institute. DOE will continue to work with the private sector, where appropriate, to accelerate progress and reduce cost in the Human Genome project.

The SC program is actively involved with other federal agencies funding, human, plant and microbial research to encourage effective and efficient management of the total federal genome research portfolio.

Recent Successes of the Office of Science:

Fueling the Future:

- Identified a major error in current models of combustion process
- Provided a realistic picture of corrosion resistance to advance protection coatings
- Created electrically conducting nano-scale ropes, 50-100 times more conductive than copper

Protecting our Living Planet:

- Research on “Conan the Bacterium” (D. Radiodurans) helps in clean-up
- Two of the 1997 “11 hottest papers in biology” were for microbial genomic sequences funded by SC
- Discovered gene for kidney disease

Exploring Energy and Matter:

- Launched the Alpha Magnetic Spectrometer experiment on the Space Shuttle to explore the mysteries of missing anti-matter and dark matter
- Established the 3-D, atom-by-atom structure of the enzyme system responsible for DNA replication
- Demonstrated that the supposedly massless neutrino must, in fact, have a non-zero rest mass.

Extraordinary Tools:

- Signed the Large Hadron Collider agreement opening the frontier of high energy physics to American researchers
- New scientific research facilities on-line: the William R. Wiley Environmental Molecular Sciences Laboratory; the Jefferson Lab’s Large Acceptance Spectrometer; SLAC’s B-Factory, the Oak Ridge Free-Air CO_2 Enrichment Facility and the JGI Production (DNA) Sequencing Facility.
- Projects on time and budget: Fermilab’s Main Injector, the Relativistic Heavy Ion Collider, the Combustion Research Facility Phase II, and the SNS.

SC Program Direction:

- Hammer award for Environmental Management Science Program
- Jointly developed the third DOE-NIH Human Genome Five Year Plan with accelerated sequencing goals
- Acknowledged as model for facilities management by the National Academy of Public Administrators (NAPA).

In addition, hundreds of principal investigators, funded by SC, win dozens of major prizes and awards sponsored by the President, the Department, the National Academy of Sciences, the National Academy of Engineering, and the major professional societies. These include the 1997 Nobel Prize for Chemistry, the 1997 Fermi and Lawrence awards, the National Science Foundation Career Award, eight of the 1998 R&D 100 awards, 1997 Discover Awards, the 1998 Federal Laboratory Consortium Award, and the 1997 and 1998 “Top Ten Contributions to Science,” reported by *Science* Magazine.

Major Program Activities for FY 2000:

The **Basic Energy Sciences** (BES) program is a principal sponsor of fundamental research for the United States in the areas of materials sciences, chemical sciences, geosciences, biosciences, and engineering sciences. This research underpins the DOE missions in energy, the environment and national security; advances energy related basic science on a broad front; and provides unique national user facilities for the scientific community. Performance measurement, dominated by peer review, helps to determine the distribution of activities supported within BES and the individual projects supported within each activity. The program funds more than 2,400 researchers at 200 institutions nationwide. Program results continue to be recognized through the receipt of major prizes and awards from the scientific community.

BES also plays a major part in the FY 2000 Office of Science initiatives described above. BES is the sole supporter of the Spallation Neutron Source construction and a major contributor to the Scientific Simulation Initiative (Combustion and Fundamental Research portions), Scientific Facilities Utilization, and the Climate Change Technology Initiative.

BES plans, constructs, and operates 18 major scientific user facilities to serve over 6,000 researchers at universities, national laboratories, and industry. These facilities enable the acquisition of new knowledge that often cannot be obtained by any other means. These facilities have an enormous impact on science and technology, ranging from determinations of the structure of superconductors and biological molecules to the development of wear-resistant prostheses; from atomic-scale characterization of environmental samples to elucidation of geological processes; and from the production of unique isotopes for cancer therapy to the development of new medical imaging technologies. As part of its commitment to excellence, BES user facilities maintain a record of less than 10 percent unscheduled downtime, on average.

Facility enhancements and maintenance activities for BES in FY 2000 will be focused on the existing high-flux neutron sources, the Los Alamos Neutron Science Center at Los Alamos National Laboratory and the High Flux Isotope Reactor at Oak Ridge National Laboratory. These improvements, recommended by the Basic Energy Sciences Advisory Committee, will substantially increase the neutron flux and instrument capabilities available to the scientific community. BES is committed to keeping the development and upgrade of scientific user facilities, including the construction of the Spallation Neutron Source, on schedule and within cost, not to exceed 110 percent of estimates.

Within the base research effort, the program in Complex and Collective Phenomena, started in FY 1999, will continue to support work at the frontiers of basic research that hold the promise of delivering revolutionary breakthroughs. This effort is designed to obtain fundamental knowledge of increasingly complex systems in order to help bridge the gap in our understanding between the atomic and molecular properties and the bulk structural and mechanical properties of materials, for example. In addition, BES will continue its Partnership for Academic-Industrial Research (PAIR) program to facilitate research partnerships between academic researchers, their students, and industrial researchers.

The **Biological and Environmental Research** (BER) program in FY 2000 will focus on sequencing the human genome, microbial genome research, low dose exposure research, environmental processes research with an emphasis on global environmental change, environmental remediation research, and radiopharmaceutical research, structural biology, and molecular nuclear medicine.

Last year, *Science* magazine identified genomic sequencing as one of the top ten breakthroughs in science. BER's Microbial Genome Program supported the complete genomic sequencing of 6 of the 18 bacteria sequenced with at least 12 more in progress. Microbial genome research continues to sequence microbes relevant to DOE mission needs including work in three main areas: (1) microbial diversity, to identify potentially useful microbes, (2) new DNA sequencing strategies to rapidly and cost effectively determine the sequence of closely related microbes, and (3) novel strategies and tools for characterizing, manipulating, and modeling entire reaction pathways or gene regulatory networks. Microbes are used as models to understand more complex biology and to advance sequencing tools.

In FY 2000, human DNA sequencing continues to ramp up. The DOE Joint Genome Institute will sequence 50 million finished bases and 70 million high quality draft bases of human DNA.

Radiopharmaceutical research and molecular nuclear medicine will continue to develop more specific and sensitive radiopharmaceutical tracers and develop sensitive imaging technology that will impact clinical medicine. Positron Emission Tomography (PET) technology, developed previously in this program, will be used to elucidate complex biomedical problems such as the neurochemical basis of addictive and neurodegenerative diseases. Recent work has shown damage to the brain function in persons addicted to drugs, such as cocaine, that reinforces the craving for these drugs. The Boron Neutron Capture Therapy Program will complete Phase I trials to determine an effective and safe treatment dose and initiate a Phase II efficacy trial. BER will continue to exploit the unique capabilities of the National Laboratories in a national biomedical engineering program to develop novel medical technologies.

In FY 2000, The Atmospheric Radiation Measurement facility will begin operations of the third climate observatory in the Tropical Western Pacific on Christmas Island, thus completing the span of observatories across the Pacific warm pool. Valuable data will result for climate model development and improvement.

The Free Air Carbon Dioxide Enrichment (FACE) experiment will continue tree growth and physiological observations, including studies of ecosystem processes. FACE technologies have achieved international recognition, with FACE facilities developing in Europe and Panama. FACE has observed the effect of increased atmospheric concentrations of carbon dioxide on tree growth and physiology.

BER facilities in support of fundamental science to underpin environmental cleanup continue to have an impact. After its first full year of operation in 1998, the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) had already attracted nearly 600 outside users and collaborators from government laboratories, private industry, and academia. Interactions between EMSL and the Natural and Accelerated Bioremediation Research (NABIR) program will be strengthened, to provide unifying research facilities for academic and laboratory investigators in the fields contributing to bioremediation research.

BER also plays a major part in the FY 2000 Office of Science initiatives described above. BER is the primary supporter of SC Genome research, and a major contributor to SSI (Global Systems and Fundamental Research portions), Scientific Facilities Utilization, and the CCTI.

The **High Energy Physics** (HEP) program will continue to address new and exciting research at the forefront of particle physics.

At Fermilab, the newly upgraded D-Zero and CDF detectors will be moved into position at the Tevatron; and they, along with the newly commissioned Main Injector, will be used for the first time for antiproton-proton collisions. The Main Injector will increase the luminosity of the Tevatron by a factor of 5. Also at Fermilab, the

NuMI/ MINOS neutrino oscillation project will be well underway with construction of conventional facilities and technical components; and the Wilson Hall Safety Improvements Project will be progressing well in its second year of physical construction with completion scheduled for 2002.

SLAC's newly commissioned B-factory, a collaboration among SLAC, Lawrence Berkeley National Laboratory, and Lawrence Livermore National Laboratory, will be in its first full year of operation with its primary goal to obtain high luminosity to begin the study of CP-violation (matter-antimatter asymmetry). Also at SLAC, physical construction on a new office building for B-factory users will begin.

As planned, the Alternating Gradient Synchrotron (AGS) at Brookhaven was transferred to the Nuclear Physics program for use as an injector for RHIC. Therefore, use of the AGS for high energy physics in FY 2000 will be on an incremental cost basis. AGS runs, necessary to achieve the precision measurement of the muon g-2 anomalous magnetic moment, will continue in FY 2000.

The fabrication of components for the LHC project continues in FY 2000. Fermilab is the host and lead laboratory for the U.S. efforts on the CMS detector as well as host and lead laboratory, with the assistance of Brookhaven and Lawrence Berkeley, on the U.S. accelerator efforts. Similarly, Brookhaven is the host and lead laboratory for the U.S. efforts on the ATLAS detector.

In addition, R&D on accelerator concepts for future large accelerator facilities will continue in FY 2000. Consistent with recent HEP Advisory Panel recommendations, modest increases are planned for high energy physics university groups in FY 2000 to allow them to exploit new facilities mentioned above.

The **Nuclear Physics** (NP) program provides primary support in the U.S. for fundamental research on the structure and fundamental forces in atomic nuclei. The Program operates large and small particle accelerator facilities located at National Laboratories and Universities which provide the microscopic probes of these structures and forces. The scope of the FY 2000 Nuclear Physics Program is broadly enhanced by operation of several new facilities. The new Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory will operate for its first full year to search for the predicted quark-gluon plasma, a heretofore unseen form of nuclear matter. The new Thomas Jefferson National Accelerator Facility in Newport News, Virginia, is fully operational, and will continue an already impressive program of research into the quark basis of the structure of nuclei. The Sudbury Neutrino Observatory (SNO) in Canada will be fully operational in FY 2000 and will be accumulating important information on the apparent low rate of neutrino flux from the sun. R&D and conceptual design development for a proposed world-class radioactive ion beam facility (ISOL) for nuclear structure and astrophysics studies, will be supported in FY 2000. A smaller radioactive ion beam facility (RIB) has recently begun to operate at Oak Ridge National Laboratory, and is prototyping new radioactive beam techniques as well as doing research.

Unique low energy heavy ion facilities at ANL and LBNL, will continue to pursue important investigations of highly deformed and exotic nuclei which require examination using very high resolution spectroscopy. The new and highly successful Gammasphere detector is being utilized at both ANL and LBNL to pursue such experiments. The MIT/Bates Linear Accelerator Center, which has been a major world center for nuclear research using electron scattering for over 25 years, will end operations in FY 2000.

The **Fusion Energy Sciences** (FES) program is completing its transition from a focus on the development of fusion as a new energy supply technology to emphasizing the science that underpins fusion energy. In FY 2000, the program will continue to make progress in understanding plasma physics, identifying and exploring innovative approaches to fusion power, and exploring the science and technology of energy producing plasmas, as a partner in the international fusion research effort.

FY 2000 will begin a three year effort, supported by FES, at the Princeton Plasma Physics Laboratory (PPPL) for the decontamination and decommissioning of the Tokamak Fusion Test Reactor (TFTR).

The program continues the move toward innovation and increased understanding of a wide range of confinement concepts. The National Spherical Torus Experiment (NSTX) facility provides strong support of the goal to explore innovative and more affordable development paths. Work on concept improvement at the exploratory level in both physics and enabling technology R&D will receive more emphasis. The inertial fusion energy element will be broadened to include research efforts on systems and related elements. This change in domestic program emphasis reflects a move away from the costly, large scale devices aimed at providing integrated plasma technology experiments operating with power plant-scale plasma parameters.

The International effort to explore the science and technology of energy producing plasmas was dramatically reduced in FY 1999 by termination of U.S. participation in the International Thermonuclear Experimental Reactor (ITER) project. The U.S. will, however, continue to pursue modest scale international collaborative activities on major international scientific facilities.

Research on high temperature toroidal plasmas will be carried out using the DIII-D facility at General Atomics, C-MOD at MIT and NSTX spherical torus at PPPL which will have its first full year of operations in FY 2000. The experimental program will be supported by broadly based theoretical, modeling and computational efforts. Technology activities supporting energy-producing plasmas will be drastically reduced as part of the shift in priorities noted above, but the long range program on low activation materials will continue. The physical and intellectual infrastructure associated with the experimental portion of energy producing plasmas will need to be re-established at an appropriate time depending upon technical advances toward lower-cost systems and/or increased urgency.

As recommended by Congress, a review of the several approaches to fusion (to be conducted by the Secretary of Energy Advisory Board) was initiated in December, 1998 and will be completed in May 1999. The National Academy of Sciences is also expected to complete a review of the fusion science program in FY 1999. Recommendations from these reviews will help to set the course for future fusion research activities.

The **Computational and Technology Research** (CTR) program supports advanced computing research — applied mathematics, high performance computing, networking, and operates supercomputer and associated facilities that are available to researchers 24 hours a day, 365 days a year. The combination of support for fundamental research, computational and networking tools development, and high-performance computing facilities provides scientists with the capabilities to analyze, model, simulate, and — most importantly — predict complex phenomena of importance to the Office of Science and the Department of Energy.

The long history of CTR accomplishments continued in FY 1999 including: the 1998 Gordon Bell Prize for Best Performance of a Supercomputing Application, the 1998 IEEE Fernbach Award for outstanding contribution in the application of high performance computers using innovative approaches and four R&D 100 Awards to CTR researchers in areas ranging from parallel numerical libraries to near frictionless coatings.

Experiments at Office of Science facilities may generate millions of gigabytes (petabytes) of data per year (which would fill the disk drives of millions of today's personal computers) presenting significant computational and communications challenges in analyzing and extracting information from the data.

Some of the pioneering accomplishments of this program are: development of the technologies to enable remote, interactive access to supercomputers; research and development leading to the High Performance Parallel Interface (HiPPI) standard; and research leading to the development of the slow start algorithm for the Transmission Control Protocol (TCP), which enabled the Internet to scale to today's worldwide communications infrastructure.

CTR is responsible for DOE participation in the Next Generation Internet (NGI) program to create the foundation for more powerful and versatile networks of the 21st century.

CTR also heads the Department's Scientific Simulation Initiative (SSI) as a joint program with the other program offices in SC. CTR's role in the SSI includes management of the selection process for a small number of basic science application efforts initiated in FY 2000, management of the SSI Advanced Computing and Communications Facilities, and management of the Computer Science and Enabling Technology component.

In addition to these computing related activities CTR also manages the Laboratory Technology Research (LTR) program for the Office of Science. The mission of this program 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 Office of Science laboratories and industry.

The Science **Program Direction** budget funds staff and related expenses which are necessary to provide overall management direction of the Office of Science research programs. The Office of Science will strive to meet staffing levels as outlined in its Workforce Management Plan. Work will continue on piloting the transfer of management responsibility of newly generated wastes at SC sites from Environmental Management to the Office of Science. The scientific and technological challenges of the Department's missions demand an adequate supply of scientists, engineers and technicians. For over 50 years, DOE and its predecessor agencies have supported science and engineering education programs involving university faculty as well as pre-college teachers and students. Tapping the significant human and physical resources of the DOE National Laboratories is perhaps the most distinguishing feature of the agency's contribution to science education. Within the FY 2000 request for Program Direction is SC's core program for science education, supporting such activities as: the Undergraduate Research Fellowship Program, the National Science Bowl, and Albert Einstein Distinguished Educator Fellowship. In addition, two new initiatives, developed in partnership with NSF, will be supported through the five SC scientific programs. The first initiative will be focused on providing pre-college science and math teachers with research opportunities that will improve their knowledge and skills of scientific discovery and enhance their ability to apply them in their classrooms. The second initiative will allow university faculty and undergraduate student teams to participate in long-term research projects at DOE Laboratories. Historically, over two-thirds of undergraduates who have participated in DOE programs have gone on to graduate school in disciplines directly related to DOE missions. These activities will help to fulfill SC's responsibilities in developing the next generation of scientists and engineers in a responsible and focused manner.

Effective human resource management will ensure that critical staffing needs are met in support of the strategic goals of the Department. This includes, but is not limited to, the integration of diversity considerations into all human resource management activities, and effective long-term succession planning for executives and scientific/ technical positions. Enhanced business processes that are built from our Activity Based Management activities and Strategic Information Planning will enable the staff to carry out the mission and functions of the organization effectively and efficiently.

Closing:

The significant increase in the FY 2000 budget for the Office of Science recognizes the critical role that fundamental knowledge plays in achieving the DOE missions and for the general advance of the Nation's economy and the welfare of its citizens. The Scientific Simulation Initiative represents a major investment in producing the necessary scientific computation and information infrastructure for DOE science applications as part of a multi-agency initiative. This request will also provide the U.S. scientific community with increased research capability and new opportunities at the DOE scientific user facilities, including progress on SNS, a new forefront neutron source, and upgrades of existing facilities. On behalf of the Administration and the Department, I am pleased to present this budget for the Office of Science and welcome the challenge to deliver results.

Martha Krebs
Director
Office of Science

Table 1

OFFICE OF SCIENCE
FY 2000 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

	FY 1998 Current Approp.	FY 1999 Current Approp.	FY 2000 Request
Science			
Basic Energy Sciences	651,816	799,524	888,084
Computational and Technology Research	146,779	157,471	198,875
Biological and Environmental Research	395,676	436,688	411,170
Fusion Energy Sciences	224,190	222,636	222,614
High Energy Physics	668,590	695,526	697,090
Nuclear Physics	314,738	334,555	342,940
Energy Research Analyses	1,434	1,000	1,000
Multiprogram Energy Laboratories-Facilities Supp	21,247	21,260	21,260
Science Program Direction	37,600	49,800	52,360
Small Business Innovation Research and Small Business Technology Transfer	80,730	——	——
Subtotal	2,542,800	2,718,460	2,835,393
General Reduction for Use of Prior Year Balances	-15,295	-13,000	——
Superconducting Super Collider	-35,000	-7,600	——
Total	2,492,505	2,697,860	2,835,393
Energy Supply R&D			
Technical Information Management	10,100	8,600	9,100
General Reduction for Use of Prior Year Balances	-68	-191	——
Total	10,032	8,409	9,100

Table 2

OFFICE OF SCIENCE
FY 2000 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

	FY 1998 Current Approp.	FY 1999 Current Approp.	FY 2000 Request
Global Climate Change	105,780	113,865	124,838
Climate Change Technology Initiative	——	13,500	33,000
Partnership for New Generation of Vehicles	5,000	5,000	5,000
Science and Education Programs	——	4,500	14,235
Strategic Simulation Initiative	——	——	70,000

Table 3

OFFICE OF SCIENCE
FY 2000 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

Major Site Funding	FY 1998 Current Approp.	FY 1999 Current Approp.	FY 2000 Request
AMES LABORATORY			
Basic Energy Sciences	18,659	17,114	16,967
Biological and Environmental Research	766	631	500
Computational and Technology Research	2,290	1,939	1,490
High Energy Physics	——	——	219
Total Laboratory	21,715	19,684	19,176
ARGONNE NATIONAL LABORATORY			
Basic Energy Sciences	139,894	143,436	145,096
Biological and Environmental Research	11,278	9,181	13,476
Computational and Technology Research	16,869	15,430	8,187
Fusion Energy Sciences	2,835	2,540	2,135
High Energy Physics	9,512	8,825	9,040
Multiprogram Energy Labs-Facilities Support	10,892	7,089	4,980
Nuclear Physics	16,845	16,045	17,485
Total Laboratory	208,125	202,546	200,399
BROOKHAVEN NATIONAL LABORATORY			
Basic Energy Sciences	76,722	77,586	77,331
Biological and Environmental Research	26,501	22,142	19,228
Computational and Technology Research	2,843	1,457	2,589
Fusion Energy Sciences	50	——	——
High Energy Physics	86,774	62,813	32,769
Multiprogram Energy Labs-Facilities Support	568	1,349	6,881
Nuclear Physics	110,851	115,900	135,549
Total Laboratory	304,309	281,247	274,347

Table 3

OFFICE OF SCIENCE
FY 2000 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

Major Site Funding	FY 1998 Current Approp.	FY 1999 Current Approp.	FY 2000 Request
THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY			
Basic Energy Sciences	200	——	——
Computational and Technology Research	190	100	283
Nuclear Physics	68,850	70,305	73,669
Total Laboratory	69,240	70,405	73,952
FERMI NATIONAL ACCELERATOR LABORATORY			
Computational and Technology Research	100	50	332
High Energy Physics	278,873	283,301	291,788
Total Laboratory	278,973	283,351	292,120
IDAHO NATIONAL ENGINEERING LABORATORY			
Basic Energy Sciences	3,478	3,609	3,020
Biological and Environmental Research	2,158	2,034	1,736
Fusion Energy Sciences	4,120	1,740	1,000
Nuclear Physics	90	80	80
Total Laboratory	9,846	7,463	5,836
LAWRENCE BERKELEY NATIONAL LABORATORY			
Basic Energy Sciences	62,160	62,553	62,095
Biological and Environmental Research	34,358	31,587	29,003
Computational and Technology Research	57,916	53,938	49,377
Energy Research Analyses	100	——	——
Fusion Energy Sciences	3,947	5,334	5,255
High Energy Physics	26,869	24,492	35,532
Multiprogram Energy Labs-Facilities Support	2,400	4,854	6,133
Nuclear Physics	21,965	22,118	18,080
Total Laboratory	209,715	204,876	205,475

Table 3

OFFICE OF SCIENCE
FY 2000 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

Major Site Funding	FY 1998 Current Approp.	FY 1999 Current Approp.	FY 2000 Request
LAWRENCE LIVERMORE NATIONAL LABORATORY			
Basic Energy Sciences	5,933	6,044	5,236
Biological and Environmental Research	30,004	36,148	28,446
Computational and Technology Research	2,755	2,940	640
Fusion Energy Sciences	10,518	11,158	10,168
High Energy Physics	1,794	685	680
Nuclear Physics	845	660	950
Total Laboratory	51,849	57,635	46,120
LOS ALAMOS NATIONAL LABORATORY			
Basic Energy Sciences	23,613	24,673	25,906
Biological and Environmental Research	19,661	20,651	18,251
Computational and Technology Research	14,614	13,034	10,894
Fusion Energy Sciences	4,143	4,219	4,419
High Energy Physics	1,090	650	790
Nuclear Physics	10,783	9,750	10,260
Total Laboratory	73,904	72,977	70,520
OAK RIDGE NATIONAL LABORATORY			
Basic Energy Sciences	110,219	217,848	302,898
Biological and Environmental Research	25,422	21,617	19,153
Computational and Technology Research	19,434	10,415	6,876
Energy Research Analyses	665	——	400
Fusion Energy Sciences	17,870	17,480	15,866
High Energy Physics	772	240	240
Multiprogram Energy Labs-Facilities Support	7,387	6,808	2,106
Nuclear Physics	16,215	15,017	16,665
Total Laboratory	197,984	289,425	364,204

Table 3

OFFICE OF SCIENCE
FY 2000 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

Major Site Funding	FY 1998 Current Approp.	FY 1999 Current Approp.	FY 2000 Request
PACIFIC NORTHWEST NATIONAL LABORATORY			
Basic Energy Sciences	12,868	12,788	12,947
Biological and Environmental Research	77,466	73,913	70,434
Computational and Technology Research	4,188	3,238	3,584
Energy Research Analyses	——	——	250
Fusion Energy Sciences	1,415	1,410	1,430
High Energy Physics	10	10	10
Total Laboratory	95,947	91,359	88,655
NATIONAL RENEWABLE ENERGY LABORATORY			
Basic Energy Sciences	4,515	4,193	3,744
Biological and Environmental Research	250	——	——
Computational and Technology Research	498	127	——
Total Laboratory	5,263	4,320	3,744
PRINCETON PLASMA PHYSICS LABORATORY			
Basic Energy Sciences	700	675	——
Computational and Technology Research	90	121	332
Fusion Energy Sciences	49,612	50,332	58,979
High Energy Physics	80	120	534
Total Laboratory	50,482	51,248	59,845
SANDIA NATIONAL LABORATORY			
Basic Energy Sciences	28,764	26,600	22,008
Biological and Environmental Research	3,486	3,239	2,903
Computational and Technology Research	5,232	5,293	3,779
Fusion Energy Sciences	5,850	4,115	3,565
Total Laboratory	43,332	39,247	32,255

Table 3

OFFICE OF SCIENCE
FY 2000 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

Major Site Funding	FY 1998 Current Approp.	FY 1999 Current Approp.	FY 2000 Request
STANFORD LINEAR ACCELERATOR CENTER			
Basic Energy Sciences	21,684	22,686	21,968
Computational and Technology Research	980	357	782
Biological and Environmental Research	3,323	2,450	2,550
Fusion Energy Sciences	50	50	50
High Energy Physics	147,502	145,017	150,231
Nuclear Physics	9	——	——
Total Laboratory	173,548	170,560	175,581

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 complex at the Brookhaven National Laboratory will be transferred to the Nuclear Physics (NP) program during FY 1999.
- *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 which are critical to the long-range viability of high energy physics research.
- *To continue to pursue international collaboration on large high energy physics projects* — Work to put into place the management and control systems needed 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.

Scientific Facilities Utilization

The High Energy Physics request includes $439,814,000 to maintain support of the Department's scientific user facilities. This investment will provide significant research time for thousands of 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), and on an incremental basis will provide support for limited operation of the Alternate Gradient Synchrotron (AGS) at the Brookhaven National Laboratory (BNL), which is primarily being operated as part of the Nuclear Physics (NP) funded Relativistic Heavy Ion Collider (RHIC) complex.

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.
- Progress on the Neutrinos at the Main Injector project as measured by accomplishment of scheduled milestones; 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.
- High Energy Physics will begin operating the B-factory at SLAC, the Main Injector for the Tevatron at Fermilab, and will deliver on the FY 2000 U.S./DOE commitments to the international Large Hadron Collider project.
- Review at least 80 percent of the research projects by appropriate peers and selected through a merit-based competitive process.
- Continue collaborative efforts with NASA on space science.

Significant Accomplishments and Program Shifts

- Completion of a long range planning study of the High Energy Physics program was accomplished 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.

Research and Technology

- 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 any of the other quarks.
- 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 considerably more precise than the best measurement from LEP.
- The world's highest precision single measurement was made by a group of university and laboratory scientists working at SLAC, of the weak mixing angle, a fundamental parameter of the Standard Model.
- The observation was made, by the CDF collaboration working at Fermilab, of the B meson containing a charmed quark. This discovery completes the theoretically predicted family of B mesons.
- 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.
- 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.
- A test of a superconducting accelerator-style magnet fabricated at Lawrence Berkeley National Laboratory (LBNL) achieved a new world record field strength of 13.5 teslas (previous record 11 teslas.) This is a significant accomplishment in the effort to advance technology for future accelerators.
- At the g-2 experiment at BNL, designed to study the magnetic properties of the muon and to develop a more precise measurement of the anomalous magnetic moment, initial data collection has been

completed. Once data collection has been completed, the analysis of these data should become available over the next three years. The experimenters are confident that they will achieve the world's best measurement of the anomalous magnetic moment of the muon. If the final result agrees with the standard model, it will place significant new limits on physics beyond the standard model.

Facility Operations

- The final data collection with the Fermilab 800 GeV fixed-target program will be completed in FY 2000, and 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 Alternating Gradient Synchrotron at BNL will be 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, use of the AGS for High Energy Physics experiments will be on an incremental cost basis.
- 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.

  The Project is proceeding well. All the civil engineering contracts have been awarded and work is underway and proceeding on schedule. Work is underway for the ATLAS detector hall, for the CMS detector hall, for a beam transfer line tunnel on the Swiss side, and for a second beam transfer line tunnel together with enlargements of the main tunnel on the French side. In addition, CERN has completed approximately 700 million Swiss francs worth of contracting for the collider, which is a significant portion of the total project budget. This includes orders placed with three companies, German, Italian and French, for two full-length collider dipole magnets from each, with an option for a third.

  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 on 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 an 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 will be provided in FY 1999, and $70,000,000 in FY 2000 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	29,740	35,260	65,000	22,150
2000	31,200	38,800	70,000	15,900
2001	32,060	37,940	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

This estimated annual funding profile is based on the needs of the LHC project and is consistent with flat out year funding for the High Energy Physics program. The profile is subject to change as additional planning detail is derived. The total of $450,000,000 from DOE for the project is firm.

Construction

- The Fermilab Main Injector Project is proceeding well and is within the planned cost and schedule profiles. All relevant milestones have been met. At the end of FY 1998, the construction phase of the project was nearly complete and commissioning was underway.
- The C-Zero Experimental Hall project at Fermilab will provide a new underground experimental area at the C-Zero location on the Tevatron ring. When completed in FY 1999, this will provide space for a new program of fixed target and modest sized collider experiments now being planned at Fermilab.
- The B-factory Project at SLAC will be completed within the planned cost and schedule profiles. At the end of FY 1998, the project was essentially complete and commissioning was underway. The physics research program, using the BaBar detector will begin during FY 1999.
- The Wilson Hall Safety Improvements Project is proceeding well. An economical, safe and effective method for repairing the structural beams has been developed and detailed planning and contracting is underway.

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

[b] The FY 1996 and FY 1997 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.

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 $373,000 and $270,000 for estimated contractor security clearances in FY 1999 and FY 2000, respectively, within this decision unit.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
High Energy Physics					
Research and Technology	209,128	215,865	-974	214,891	227,190
Facility Operations	408,612	459,635	0	459,635	441,200
Subtotal, High Energy Physics	617,740	675,500	-974	674,526	668,390
Construction	50,850	21,000	0	21,000	28,700
Subtotal, High Energy Physics	668,590	696,500	-974	695,526	697,090
Use of Prior Year Balances	-1,851 [a]	-1,610 [a]	0	-1,610 [a]	0
General Reduction	0	-974	+974	0	0
Total, High Energy Physics	666,739 [b]	693,916	0	693,916	697,090

Public Law Authorization:

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

[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 $12,833,000 which has been transferred to the SBIR program and $770,000 which has been transferred to the STTR program.

Funding by Site

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	%Change
Albuquerque Operations Office					
Los Alamos National Laboratory	1,090	650	790	+140	+21.5%
Chicago Operations Office					
Ames Laboratory	0	0	219	+219	+100.0%
Argonne National Laboratory	9,512	8,825	9,040	+215	+2.4%
Brookhaven National Laboratory	86,774	62,813	32,769	-30,044	-47.8%
Fermi National Accelerator Laboratory	278,873	283,301	291,788	+8,487	+3.0%
Princeton Plasma Physics Laboratory . .	80	120	534	+414	+345.0%
Total, Chicago Operations Office	375,239	355,059	334,350	-20,709	-5.8%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	26,869	24,492	35,532	+11,040	+45.1%
Lawrence Livermore National Laboratory	1,794	685	680	-5	-0.7%
Stanford Linear Accelerator Center	147,502	145,017	150,231	+5,214	+3.6%
Total, Oakland Operations Office	176,165	170,194	186,443	+16,249	+9.5%
Oak Ridge Operations Office					
Oak Ridge Institute for Science Education	230	100	489	+389	+389.0%
Oak Ridge National Laboratory	772	240	240	0	0.0%
Total, Oak Ridge Operations Office	1,002	340	729	+389	+114.4%
Richland Operations Office					
Pacific Northwest National Laboratory . .	10	10	10	0	0.0%
All Other Sites [a]	115,084	169,273	174,768	+5,495	+3.2%
Subtotal, High Energy Physics	668,590	695,526	697,090	+1,564	+0.2%
Use of prior year balances	-1,851 [b]	-1,610 [b]	0	+1,610 [b]	+100.0%
Total, High Energy Physics	666,739 [c]	693,916	697,090	+3,174	+0.5%

[a] Funding provided to universities, industry, other federal agencies and other miscellaneous contractors.

[b] 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.

[c] Excludes $12,833,000 which has been transferred to the SBIR program and $770,000 which has been transferred to the STTR program.

Site Description

Ames Laboratory

Ames Laboratory is a Mulitiprogram Laboratory located on 10 acres in Ames, Iowa. Educational activities supported at the laboratory are directed towards providing opportunities for pre-college teachers that will participate directly in cutting-edge research at DOE science laboratories, and will renew their understanding of scientific investigation.

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, 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 collider, 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 funds research at 106 colleges/universities located in 38 states. This line also includes funding of research awaiting distribution pending completion of peer review results or program office detailed planning.

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 Facility Operations subprogram, described later, provides the large facilities — accelerators, detectors, colliding beams 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 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) carry out R&D in support of existing accelerator and detector facilities aimed at maintaining and improving their performance parameters and cost effectiveness; 2) carry out R&D in support of planned and proposed projects to maximize their performance goals and cost effectiveness; 3) carry out R&D to transfer new concepts and technologies into practical application in the High Energy Physics context; and 4) carry out R&D to search for and develop new concepts and ideas which could lead to significant enhancements of 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.

The High Energy Physics program will provide opportunities for pre-college teachers that will participate directly in cutting-edge research at DOE science laboratories, and will renew their understanding of scientific investigation. Where teachers do not possess sufficient background to participate directly in research, DOE will provide mediated research experiences where teachers can work with teams of scientists and science educators to understand the nature of DOE's scientific research. The goal is to provide educators with the tools to sharpen their science and math foundations and apply these tools to their classroom practice. Funds will be provided to pay for teachers' stipends, travel, housing and subsidize laboratory scientists' time for this activity ($2,921,000).

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Physics Research	143,592	145,835	159,650	+13,815	+9.5%
High Energy Technology	65,536	69,056	67,540	-1,516	-2.2%
Total, Research and Technology	209,128	214,891	227,190	+12,299	+5.7%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Physics Research			
■ **Fermilab:** In FY 2000 the experimental physics research groups at Fermilab will be working on completing and bringing into operation the upgraded CDF and D-Zero facilities, completing a fixed target run, analyzing data from recent experimental data taking runs, and preparing for future experiments including participation in the CMS detector for LHC. The theoretical research group and the theoretical astrophysics group will be working on a variety of theoretical topics.	10,415	8,826	9,240
■ **SLAC:** The experimental physics research groups at SLAC will concentrate their efforts in FY 2000 on the physics analysis and interpretation of the large amounts of data taken with the SLC Large Detector (SLD) detector in prior years, and on early data-taking with the recently commissioned BaBar detector facility and B-factory. Some physics research will also be done in a fixed target experiment studying parity violation, and with the CLEO detector at the Cornell Electron Storage Ring (CESR) facility at Cornell. The theoretical physics group will continue to emphasize topics related to the SLD, BaBar, and Next Linear Collider (NLC) research programs as well as tests of the Standard Model and Quantum ChromoDynamics (QCD).	11,411	12,027	12,441
■ **BNL:** In FY 2000, the BNL experimental physics research groups will be working on experiments at the BNL-AGS involving precision measurements of the muon magnet moment, and rare decays of the K meson; on the Fermilab collider experiment D-Zero probing the high energy frontier; and on the U.S. effort on the Large Hadron Collider ATLAS detector. The Theoretical physics research groups will be working on a number of topics.	7,662	7,690	8,226

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **LBNL:** In FY 2000, LBNL researchers will be analyzing data recently taken at the collider detectors and at fixed target experiments at Fermilab, and will be preparing for studies of B-Bbar decays using the BaBar detector on the B-factory at SLAC. The researchers will also be working on supernova measurements to establish values for cosmological parameters. Recent results indicate the universe may be expanding at an increasing rate. The Particle Data Group at LBNL continues as an international clearinghouse for particle physics information.	10,375	10,498	11,033
■ **ANL:** 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.	5,489	5,465	5,465
■ **Universities and Other Laboratories:** The University Program consists of groups at 100 universities doing experiments (77 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. Provides support for research scientists at LANL, LLNL, ORNL, and PNNL. This University and small laboratory (LANL, LLNL, ORNL, PNNL) based research activity is described in more detail below. The recent HEPAP Subpanel (Gilman), recommended that the level of funding for the university based portion of the program be substantially increased over inflation over the next two year period. The funding detailed below includes funding for 3.5 percent over inflation providing more than half of the recommended first year increase. These increases are aimed at improving the research capabilities and operational effectiveness of these (primarily) university based research groups.			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
▸ **University and other laboratory based Research using Fermilab:** Some 55 DOE-funded universities participate in large international collaborations doing experiments at Fermilab. LLNL is also involved in the MINOS project. 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. 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 fixed target 800 GeV experiments diminish and CMS, MINOS, and BTeV related activities increase.	24,905	25,170	26,940
▸ **University and other laboratory based Research using SLAC:** Some 27 DOE–funded universities participate in large international collaborations doing experiments at SLAC. LLNL is also involved in the BaBar detector project. The experiments involve the SLD and BaBar detectors, and other smaller detectors for fixed target experiments. 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.	9,960	10,360	11,400
▸ **University based Research using 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 external storage rings measuring the muon anomalous magnetic moment to high precision. This participation has decreased significantly due to the phasing out of most of the AGS High Energy Physics program.	3,980	2,960	2,070

	(dollars in thousands) FY 1998	FY 1999	FY 2000
▸ **University based Research using the Cornell Electron Storage Rings:** 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. They help to plan, build, execute, analyze and publish the experiments. This participation has been decreasing, as some groups move to BaBar at SLAC.	4,980	4,440	4,145
▸ **University and other laboratory based Research not using accelerators:** Some 28 DOE-funded universities are involved in High Energy Physics experiments not utilizing accelerators. LANL, LLNL and PNNL are also involved in non-accelerator experiments. These experiments, which are primarily in the areas of astrophysics and cosmology, include MACRO (Italy), Super-Kamiokande (Japan), SNO (Canada), CHOOZ (France), SOUDAN (Minnesota), CDMS (Stanford), GRANITE (Mt. Hopkins, Arizona), Palo Verde (Arizona) and AMS (Space Station). They help build the detectors, plan, execute, analyze and publish the results. This participation has increased and is expected to increase further due to the newly emerging interest and opportunities in astrophysics and cosmology, such as GLAST, AUGER and CDMS (Soudan). The funding includes an increase of $1,800,000 for the fabrication of underground detectors such as those listed above. The allocation of these funds will be decided on the basis of a peer review process which is presently underway.	12,950	15,300	18,115
▸ **University and other laboratory Theoretical Studies:** Some 75 universities with DOE funding participate in research in theoretical high energy physics. Theoretical studies at LANL are also included here. This effort is expected to remain about constant. They provide theoretical ideas, concepts, calculations and simulations of physical processes in high energy physics.	18,920	19,250	20,720

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
▸ **University based Research using 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). They help to fabricate the detectors and experimental apparatus, plan and execute the experiments, analyze the data and publish the results. The participation has increased and is expected to increase further with the participation in the ATLAS and CMS detectors at CERN's LHC. The funding includes an increase of $1,000,000 to address technical infrastructure needs, such as technical staff and computers, related to research operations at foreign laboratories.	20,925	22,700	26,930
▸ **Other University and other laboratory based Research activities:** A new focussed program in Detector R&D, recommended by the HEPAP Subpanel, was started modestly in FY 1999, will be continued and expanded slightly ($1,000,000). The Outstanding Junior Investigator program, which 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 in new awards per year. A new educational program, Quark-Net, aimed at involving high school students and teachers in high energy physics research, will be started in FY 1999 and will continue at $250,000. The accelerator and beamline shielding studies carried out at ORNL are included here. Funding of conferences, studies, and workshops is also included here. The funding includes an increase of $500,000 to increase the capability of the computer network link to CERN and an increase of $750,000 for anticipated but unknown needs or opportunities which is not yet allocated.	1,620	1,149	2,925
Total, Universities and Other Laboratories	98,240	101,329	113,245
Total, Physics Research	143,592	145,835	159,650

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
High Energy Technology			
■ **Fermilab:**			
▸ **Accelerator R&D:** Activities in FY 2000 include design of an improved proton source; design of an electron cooling system to improve antiproton beam quality: construction of a large-scale experiment to test the concept of ionization cooling, which is critical for any future muon collider; R&D on superconducting magnets and other components for future 100 TeV proton colliders; and tests of accelerating electrons with plasma wake-fields driven by intense electron beams. Muon collider R&D, with a high priority in the National High Energy Physics program, will increase in FY 2000. The proposed funding provides an approximately constant level of effort, except for the increase to permit the critical muon collider experiment to proceed.	9,221	7,670	8,670
▸ **Experimental Facilities R&D:** Activities in FY 2000 include: R&D on the feasibility of reducing the cell size in the CDF detector wire chamber to accommodate the higher track density that will result from increasing the Tevatron collider event rate; developing scintillating fibers for the D–Zero detector that are capable of withstanding the increased radiation level resulting from the increased collision rates; 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. The proposed funding provides a slightly decreasing level of effort.	8,700	6,670	6,670
Total, Fermilab	17,921	14,340	15,340

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **SLAC:**			
▸ **Accelerator R&D:** Activities in FY 2000 include R&D to explore new concepts in accelerator physics in support of design of future linear colliders. The R&D on the design for a linear collider to operate with TeV scale center of mass energy will be reduced to $12,000,000 in FY 2000. Relevant areas are high powered radio frequency systems, accelerator structures, controls and instrumentation, and advanced beam optics. This R&D and design activity is being done in the context of an international collaboration. R&D in support of the B-factory, commissioned in FY 1999, will continue at a significant level to ensure a strong luminosity performance in the initial data run for physics research. The R&D programs in generic collider R&D will continue, and the program in advanced accelerator physics looking at the use of lasers, plasmas, and ultra high frequency radio frequency systems, will be given slightly increased priority.	14,651	16,500	11,900
▸ **Experimental Facilities R&D:** In FY 2000, the focus will be on instrumentation for physics studies in the center of mass collision energy range of 50 GeV to 5,000 GeV. This will include work to support and improve performance of BaBar, the newly operating B-factory detector, and an expanded program of R&D, consistent with the recommendations of the HEPAP Subpanel, on developing preliminary designs for a detector to operate with a new electron-positron linear collider operating at the TeV center of mass energy scale.	1,545	2,500	2,900
Total, SLAC	16,196	19,000	14,800

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **BNL:**			
▸ **Accelerator R&D:** Activities in FY 2000 will include, R&D on new methods of particle acceleration such as laser acceleration and Free Electron Laser (FEL) accelerators, primarily using the excellent capabilities of the BNL Accelerator Test Facility. R&D on the muon collider concept will be expanded and will include design work on key system components including the high field solenoid and the dipole magnets. In the BNL superconductor test facility the characterization of new high critical temperature superconductors as well as their special requirements for magnet fabrication should be better understood. With the transfer of the AGS to the Nuclear Physics program during FY 1999, Accelerator R&D in support of the AGS is being brought to an orderly close.	5,570	5,045	5,155
▸ **Experimental Facilities R&D:** In FY 2000, 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-wolfrate crystals with improved light output will continue. Testing of the modules that constitute the ATLAS barrel calorimeters will begin.	3,065	1,075	1,075
Total, BNL	8,635	6,120	6,230
■ **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. LBNL has a major role in designing, building, and testing the Low Energy Ring at the B-factory. In FY 1999, the B-factory will be fully commissioned. In FY 2000, 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, all-optical, laser-plasma wakefield accelerator at LBNL will begin accelerating electron bunches.	6,935	6,905	7,565

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
▸ **Experimental Facilities R&D:** LBNL leads in providing 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 2000, work will continue on large format CCDs and high-resolution imaging systems, plus the production and testing of IC systems.	2,620	2,670	2,670
Total, LBNL	9,555	9,575	10,235
■ **ANL:**			
▸ **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. Using this new technique, accelerating gradients at one-third of conventional levels have been reached. Thus there is optimism that the much higher gradient predicted by theory can be achieved. Planning will be underway for an upgraded experimental facility which could generate much higher gradients. In addition, work will be undertaken on muon collider R&D as recommended by the HEPAP Subpanel.	1,135	1,130	1,305
▸ **Experimental Facilities R&D:** In FY 2000 work will be underway on the MINOS detector, the ATLAS detector for the LHC, and a possible upgrade of the ZEUS detector at DESY.	900	920	920
Total, ANL	2,035	2,050	2,225

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Universities, Other Laboratories, and Other Contractors:**			
▸ **University Program:** The funding will provide for a program of high priority technology R&D 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. This element also includes the portion of the increased funding for R&D on future facility concepts as summarized in the table below which has not yet been allocated. Discussions and peer reviews are underway to design an optimum overall program and to identify and fund key activities. In FY 1998 $770,000 was transferred to the STTR program. Additional funding for the SBIR program is contained in the Facility Operations subprogram.	11,194	17,971	18,710
Total, High Energy Technology	65,536	69,056	67,540
Total, Research and Technology, ...	209,128	214,891	227,190

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ **Physics Research**	
▸ An increase in the base funding for the university program as recommended by the HEPAP.	+6,475
▸ An increase in the funding for the fabrication of non accelerator experiments as recommended by the HEPAP.	+1,800
▸ An increase to initiate an expanded program of detector R&D as recommended by the HEPAP.	+600
▸ An increase to provide for additional R&D to address the computing and networking needs of the new generation of detectors.	+1,500
▸ Initiation of an education program at National Laboratories.	+2,921

	FY 2000 vs. FY 1999 ($000)
▸ An increase in the funds held for allocation pending completion of planning and peer review activities.	+519
Total, Physics Research	+13,815
■ **High Energy Technology**	
▸ An increase in the funding for muon collider R&D at Fermilab	+1,000
▸ A decrease in the funding for NLC R&D at SLAC.	-5,000
▸ An increase in other Technology R&D at SLAC.	+800
▸ An increase in the funding for muon collider R&D at BNL.	+980
▸ Termination of the program of accelerator R&D at the AGS.	-870
▸ An increase in the funding of muon collider R&D at LBNL.	+660
▸ An increase in the funding for muon collider R&D at ANL.	+175
▸ An increase in the base funding for the advanced accelerator R&D program.	+620
▸ An increase in the funding held for allocation pending completion of planning and peer review activities.	+119
Total, High Energy Technology	-1,516
Total Funding Change, Research and Technology	+12,299

The following table summarizes the above changes for possible future HEP facilities:

	(dollars in millions)		
	FY 1998	FY 1999	FY 2000
Next Linear Collider	10.0	17.0	12.0
Muon-Muon Collider	4.5	5.5	8.2
Very Large Hadron Collider	2.5	3.0	3.0

Facility Operations

Mission Supporting Goals and Objectives

The Facility Operations subprogram includes the provision and operation of the large accelerator and detector facilities which are 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, at Fermilab and SLAC, waste management activities. 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 Lawrence Berkeley National Laboratory, Fermi National Accelerator Laboratory and Stanford Linear Accelerator Center are also included. Accelerator Improvement Projects (AIP) funding support for additions and modifications to accelerator facilities which are supported by the High Energy Physics research program is also included.

The principal objective of the Facility Operations 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 Facility Operations 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.
- High Energy Physics will begin operating the B-factory at SLAC, the Main Injector for the Tevatron at Fermilab.

Planned Accelerator Operations

(in weeks)

	FY 1998	FY 1999	FY 2000
Fermilab	13	38	29
SLAC	33	42	39
BNL	12	14	8

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Fermi National Accelerator Laboratory	191,195	210,145	212,743	+2,598	+1.2%
Stanford Linear Accelerator Center	107,745	111,290	118,290	+7,000	+6.3%
Brookhaven National Laboratory	59,367	42,882	5,347	-37,535	-87.5%
Universities and Other Laboratories	10,345	25,408	29,910	+4,502	+17.7%
Large Hadron Collider	35,000	65,000	70,000	+5,000	+7.7%
Waste Management	4,960	4,910	4,910	0	0.0%
Total, Facility Operations	408,612	459,635	441,200	-18,435	-4.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000

Fermilab

Provides support for operation, maintenance, improvement, and enhancement of the Tevatron accelerator and detector complex. This complex includes the Tevatron, which can operate in a collider mode with protons and anti-protons, or in a fixed target mode with protons only; the new Main Injector which 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 detectors – CDF and D-Zero – and a number of fixed target experiments in the external beams areas.

- **Accelerator Operation:** In FY 2000, the upgraded Tevatron complex will be operated for about 6 weeks ending a fixed target run begun in FY 1999. This will be followed by 8 weeks of commissioning of the Main Injector and 15 weeks of operation of the Tevatron in collider mode with the higher luminosity available from the newly completed Main Injector. The funds requested will provide for the operation of the Tevatron, the Main Injector, the Booster, the Linac and the antiproton source as needed. The reduction in capital expenditures resulting from the completion of the CDF and D-Zero detector upgrade projects is partially offset by the planned increase for the MINOS Detector. . . . . 116,910 | 126,535 | 126,333

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
■ **Experimental Facility Operations:** In FY 2000, the upgrades of the CDF and the D-Zero detectors will be completed and the upgraded detectors will be brought into operation. In addition, the funding will support the active experiments in the completion of the fixed target run. The funding will also be used to provide the computing resources needed for the analysis of existing data and the planning and design of future experiments.	74,285	83,610	86,410
Total, Fermilab	191,195	210,145	212,743

Tevatron Operation

	FY 1998	FY 1999	FY 2000
	(in weeks)		
Fixed Target	0 [a]	22	6
Collider	0 [a]	0	15
Commissioning	13	16	8
Total, Tevatron Operation	13	38	29

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 and the SLC, and to these is being added the B-factory completed in FY 1999. The detector facilities include the SLD, the End Station A experimental set-ups, and BaBar, the detector which is being constructed for use with the B-factory. Also provides for maintenance of the laboratory physical plant.

[a] Operation of the Tevatron in collider or fixed target mode in FY 1998 is precluded by the long shutdown needed for completion of the Fermilab Main Injector project.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
▪ **Accelerator Operation:** Accelerator operations at SLAC in FY 2000 will concentrate heavily on about 9 months of strong utilization of the newly completed asymmetric B-factory colliding beam storage rings in order to maximize the data collected by the BaBar detector facility. The linac will serve primarily as the injector of positrons and electrons to the B-factory storage rings during this time, although a 5 month parasitic run of a fixed target experiment at the full linac energy is also planned. Includes initial Major Item of Equipment (MIE) funding ($3,000,000) for the fabrication of a portion of the Gamma-ray Large Area Space Telescope (GLAST) project. GLAST, a high sensitivity space based instrument for the study of high energy gamma rays, is planned as a joint DOE-NASA project and has the potential for significant contributions from a number of foreign collaborators. SLAC is the lead laboratory for the DOE portion of the project. Total estimated cost is subject to further negotiations with NASA and potential foreign collaborators.	82,228	79,300	84,500
▪ **Experimental Facility Operations:** Experimental facility operations will emphasize running the newly completed BaBar detector facility, which will be the priority research program at SLAC in FY 2000. The End Station A complex will also be operated during the fixed target run.	25,517	31,990	33,790
Total, SLAC	107,745	111,290	118,290

SLAC Operation

	(in weeks)		
	FY 1998	FY 1999	FY 2000
SLC	16	0	0
Fixed Target	0	10	15[a]
B-factory Commissioning	17	16	0
B-factory Operation	0	16	39
Total, SLAC Operation	33	42	39

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

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
BNL			
Provides support for the operation, maintenance, improvement, and enhancement of the accelerator and detector complex on the BNL site. The principal facility is the AGS and its complement of experimental set ups. The AGS was transferred to the Nuclear Physics program during the 3rd quarter of FY 1999 to be operated as part of the RHIC facility. In FY 2000, the AGS operation for the HEP program will be on an incremental cost basis.			
■ **Accelerator Operation:** 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 2000 will be a eight week run for the muon magnetic moment experiment. Includes, in FY 1998 and FY 1999, but not FY 2000 landlord GPP and GPE funding..	38,332	29,672	3,047
■ **Experimental Facility Operations:** Provides for eight weeks of operation of the muon magnetic moment experiment and general support activities in the experimental areas.	21,035	13,210	2,300
Total, BNL	59,367	42,882	5,347

AGS Operation

	(in weeks)		
	FY 1998	FY 1999	FY 2000
AGS Operation for HEP	12	14	8

Universities and Other Labs			
Provides for capital equipment funding at ANL, LBNL, some smaller DOE labs, and for university based researchers. Provides landlord GPP and GPE for LBNL beginning in FY 2000. Includes $14,735,000 in FY 1999 and $15,015,000 in FY 2000 for the SBIR and STTR programs. Provides for certain computer networking expenses.	10,345	25,408	29,910

Large Hadron Collider

- In FY 1998 and FY 1999, 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 and RF accelerating cavities for the colliding beam intersection regions. Activities on the detectors will include R&D and prototype development of subsystems such as

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
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

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
Facility Operations			
LHC			
Accelerator Systems			
Operating Expenses	4,315	7,070	600
Capital Equipment	9,685	8,330	19,500
Total, Accelerator Systems	14,000	15,400	20,100
Procurement from Industry	0	14,340	11,100
ATLAS Detector			
Operating Expenses	4,416	8,440	4,900
Capital Equipment	5,634	2,760	10,600
Total, ATLAS Detector	10,050	11,200	15,500
CMS Detector			
Operating Expenses	5,650	14,550	14,110
Capital Equipment	5,300	9,510	9,190
Total, CMS Detector	10,950	24,060	23,300
Total, LHC	35,000	65,000	70,000

	FY 1998	FY 1999	FY 2000
▸ **Accelerator Systems:** In FY 2000, funding will support continuation of the production of interaction region quadrupole magnets, feedboxes, and absorbers; production of RF region dipoles; superconducting cable testing and support; and accelerator physics design studies.	14,000	15,400	20,100
▸ **Procurement from Industry:** Funding will support reimbursement to CERN for purchases from U.S. industry including superconducting wire, cable, and cable insulation materials.	0	14,340	11,100

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
▸ **ATLAS Detector:** In FY 2000, funding will support the production of silicon strips, transition radiation tracker (TRT) modules, barrel cryostat and feedthroughs, front end electronics for the liquid argon calorimeter, the extended barrel tile calorimeter and electronics, the monitored drift tube muon chambers and electronics, and the alignment system for the muon spectrometer. The funding will also provide for advanced prototypes: the readout drivers (RODs) for the silicon and liquid argon systems, the TRT electronics, the electronic system for the liquid argon calorimeter. The R&D will be concluding for the pixel detectors while continuing for the trigger and data acquisition system.	10,050	11,200	15,500
▸ **CMS Detector:** In FY 2000, funding will support work on three of the subsystems in CMS. The endcap muon system will have set up the cathode strip chamber factory in FY 1999, and will be in full production. The hadron calorimeter system will have completed the two preproduction prototypes in FY 1999 and be in full production of copper absorber and the optics. The magnet system will complete the procurement of the majority of the items for the barrel and endcap steel flux return and the coil vacuum tank. The electromagnetic calorimeter subsystem will include procurement of front end transducers and electronics. The trigger/data acquisition and forward pixel subsystems will still be in an engineering phase.	10,950	24,060	23,300
Total, LHC	35,000	65,000	70,000
Waste Management			
■ Continues the pilot program concerning packaging, shipment and disposition of hazardous, radioactive or mixed waste generated in the course of normal operations at Fermilab and SLAC. This pilot program is intended to evaluate opportunities to reduce the volume of newly generated waste and its associated management and disposal costs..	4,960	4,910	4,910
Total, Facility Operations	408,612	459,635	441,200

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ **Fermilab**	
▸ An increase to support full operation of the facility.	+5,600
▸ An increase in GPP.	+999
▸ A decrease in equipment funding reflecting the completion of the CDF and D-Zero detectors offset by increase in the funding for the NuMI/Minos detector.	-4,001
Total, Fermilab	+2,598
■ **Stanford Linear Accelerator Center**	
▸ An increase to support full utilization of the B-factory.	+5,300
▸ An increase in AIP and GPP.	+1,700
Total, Stanford Linear Accelerator Center	+7,000
■ **Brookhaven National Laboratory**	
▸ A decrease reflecting the transfer of the AGS to the NP program.	-28,175
▸ A decrease reflecting the transfer of landlord responsibilities (GPP, GPE) to NP.	-9,360
Total, Brookhaven National Laboratory	-37,535
■ **Universities/Other**	
▸ An increase reflecting primarily the addition of the landlord responsibilities (GPP, GPE) at LBNL to HEP.	+4,502
■ **Large Hadron Collider**	
▸ An increase to follow the agreed profile.	+5,000
Total Funding Change, Facility Operations	-18,435

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.

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Construction	50,850	21,000	28,700	+7,700	+36.7%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Fermilab Main Injector Project:** This project provides for a new accelerator to replace the injector accelerator for the Tevatron complex. The present injector for the Tevatron is the original Fermilab main ring which is less than fully adequate and nearing the end of its useful lifetime. The accelerator will be commissioned and the project completed during FY 1999.	30,950	0	0
■ **SLAC Master Substation Upgrade:** This project provides for an upgrade and reconfiguration of the main electric power substation on the SLAC site. Obsolete (and hazardous) switch gear will be replaced and load balancing will be implemented thus extending the useful life of the existing main 230 kv transformers. Procurement of long lead switch gear items was initiated in FY 1997, and the project will be completed by the end of FY 1998.	9,400	0	0
■ **Neutrinos at the Main Injector (NuMI):** This project provides for the construction of new facilities at Fermilab and at the Soudan Underground Laboratory in Soudan, Minnesota which are especially designed for the study of the properties of the neutrino and in particular to search for the neutrino oscillations. The FY 2000 funding is for continued detailed design and initiation of construction of conventional facilities and technical components.	5,500	14,300	22,000

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **C-Zero Area Experimental Hall:** This project provides for the construction of a new experimental hall at the C-Zero location on the Fermilab Tevatron ring. This will be used to house modest sized collider and fixed target experiments in a new experimental program being planned at Fermilab. This project will be completed in FY 1999.	5,000	0	0
■ **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.	0	6,700	4,700
■ **SLAC Research Office Building:** This project provides urgently needed office space for the substantial expansion of visiting scientists, or "users", which will occur when the B-factory becomes 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	0	2,000
Total, Construction	50,850	21,000	28,700

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ Continuation of the Wilson Hall Safety Improvement Project at Fermilab.	-2,000
■ Continuation of the Fermilab NuMI project.	+7,700
■ Initiation of the Research Office Building.	+2,000
Total Funding Change, Construction	+7,700

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1998	FY 1999	FY 2000 Request	$ Change	% Change
General Plant Projects	13,455	14,841	12,985	-1,856	-12.5%
Accelerator Improvement Projects	5,963	10,186	10,885	+699	+6.9%
Capital Equipment	93,539	76,363	90,315	+13,952	+18.3%
Total, Capital Operating Expense	112,957	101,390	114,185	+12,795	+12.6%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1998	FY 1999	FY 2000 Request	Unapprop-riated Balance
92-G-302 Fermilab Main Injector	229,600	198,650	30,950	0	0	0
97-G-303 SLAC Master Substation Upgrade	12,400	3,000	9,400	0	0	0
98-G-304 Neutrinos at the Main Injector	76,200	0	5,500	14,300	22,000	34,400
98-G-305 C-Zero Area Experimental Hall	5,000	0	5,000	0	0	0
99-G-306 Wilson Hall Safety Improvements . .	15,600	0	0	6,700	4,700	4,200
00-G-307 SLAC Office Building	7,200	0	0	0	2,000	5,200
Total Construction		201,650	50,850	21,000	28,700	43,800

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1998	FY 1999	FY 2000 Request	Accept-ance Date
D-Zero Upgrade	55,270	28,467	14,525	9,555	2,723	FY 2000
CDF Upgrade	54,957	27,957	13,525	9,555	3,920	FY 2000
B-factory detector (BaBar)[a]	68,000	43,000	21,700	3,300	0	FY 1999
Antimatter in Space	3,192	2,992	200	0	0	FY 1998
Super-Kamiokande	3,584	3,053	531	0	0	FY 1998
Large Hadron Collider — Machine [a]	90,615	0	11,485	8,330	19,500	FY 2005
Large Hadron Collider — ATLAS Detector [a]	63,424	0	5,634	2,760	10,600	FY 2005
Large Hadron Collider — CMS Detector [a]	55,950	0	5,300	9,510	9,190	FY 2005
MINOS	45,000	0	0	2,000	5,868	FY 2002
GLAST[b]	N/A	0	0	0	3,000	N/A
Total, Major Items of Equipment		105,469	72,900	45,010	54,801	

[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.

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

(Changes from FY 1999 Congressional Budget Request are denoted with a vertical line [|] in the left margin.)

Significant Changes

Total Estimated Cost and Total Project Cost have been adjusted due to changes in the construction 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

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Design			
1998	5,500	5,500	1,140
Construction			
1999	14,300	14,300	8,360
2000	22,000	22,000	26,300
2001	23,000	23,000	27,000
2002	11,400	11,400	11,900
2003	0	0	1,500

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 which 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 which 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 which 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 which 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	7,720
Design Management costs (0.0% of TEC)	10	8
Project Management costs (0.0% of TEC)	20	22
Total, Engineering design inspection and administration of construction costs (9.4% of TEC)	7,180	7,750
Construction Phase		
Buildings	8,320	2,880
Special Equipment	10,120	10,270
Other Structures	30,960	38,690
Construction Management (6.0% of TEC)	4,590	540
Project Management (2.8% of TEC)	2,170	1,620
Total, Construction Costs	56,160	54,000
Contingencies		
Design Phase (2.8% of TEC)	2,172	not available
Construction Phase (14.0% of TEC)	10,688	not available
Total, Contingencies (16.8% of TEC)	12,860	14,050
Total, Line Item Cost (TEC)	76,200	75,800

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 1998	FY 1999	FY 2000	Outyears	Total
Project Cost						
Facility Cost						
Total, Line item TEC	0	1,140	8,360	26,300	40,400	76,200
Other Project Costs						
Capital equipment [a]	0	0	2,000	5,868	36,357	44,225
R&D necessary to complete construction [b]	450	810	40	0	0	1,300
Conceptual design cost [c]	630	200	0	0	0	830
Other project-related costs [d]	0	1,520	960	7,632	3,433	13,545
Total, Other Project Costs	1,080	2,530	3,000	13,500	39,790	59,900
Total Project Cost (TPC)	1,080	3,670	11,360	39,800	80,190	136,100

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

[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 1999 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

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Construction			
1999	6,700	6,700	1,690
2000	4,700	4,700	6,340
2001	4,200	4,200	6,990
2002	0	0	580

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	920	920
Project Management costs (0.0% of TEC)	100	100
Total, Engineering design inspection and administration of construction costs (6.5% of TEC)	1,020	1,020
Construction Phase		
Buildings	8,850	8,850
Inspection, design and project liaison, testing, checkout and acceptance	870	870
Construction Management (11.7% of TEC)	1,820	1,820
Project Management (2.8% of TEC)	430	430
Total, Construction Costs	11,970	11,970
Contingencies		
Design Phase (1.1% of TEC)	170	170
Construction Phase (15.6% of TEC)	2,440	2,440
Total, Contingencies (16.7% of TEC)	2,610	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 1998	FY 1999	FY 2000	Outyears	Total
Project Cost						
Facility Cost						
Total, Line item TEC	0	0	1,690	6,340	7,570	15,600
Other Project Costs						
Conceptual design cost	530	270	0	0	0	800
Other project-related costs [a]	0	0	560	380	1,460	2,400
Total, Other Project Costs	530	270	560	380	1,460	3,200
Total Project Cost (TPC)	530	270	2,250	6,720	9,030	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 1999 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

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 Central 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 will allow the demolition of thirteen very old, temporary structures, totaling approximately 20,000 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 basics 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 is scheduled to begin operation in FY 1999, expects a large influx of Users who will require adequate office and support space. SLAC expects to host approximately 1,100 HEP Users per year when the BaBar experiment begins 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 even 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, 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 20,000 square feet of temporary space to be removed.

If the new Central 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.

Funding is requested to initiate Preliminary and Final Design (Title I and II) of the project, procuring an Architect/Engineering firm to develop and oversee design, procure equipment, and begin construction.

4. Details of Cost Estimate [a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs (5.8% of total estimated cost (TEC))	419	NA
Design Management costs at 23% of Preliminary and Final Design	98	NA
Project Management costs at 23% of Preliminary and Final Design	98	NA
Total, Design Phase	615	NA
Construction Phase		
Building	4,727	NA
Specialized Utilities	519	NA
Standard Equipment	496	NA
Construction Management at 2% of above	113	NA
Project Management at 1.5% of above	85	NA
Total, Construction Costs	5,940	NA
Contingencies at approximately 10 percent of above costs		
Design Phase (0.8% of TEC)	61	NA
Construction Phase (8.1% of TEC)	584	NA
Total, Contingencies	645	NA
Total, line item costs	7,200	NA

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 1998	FY 1999	FY 2000	Outyears	Total
Project Cost						
Facility Cost						
Design	0	0	0	615	0	615
Construction	0	0	0	335	6,250	6,585
Total Facility Costs (TEC)	0	0	0	950	6,250	7,200
Other Project Costs						
Conceptual design cost	0	0	30	0	0	30
Other project related costs [a]	0	0	0	0	200	200
Total, Other Project Costs	0	0	30	0	200	230
Total Project Cost (TPC)	0	0	30	950	6,450	7,430

7. Related Annual Funding Requirements

(FY 1998 dollars in thousands)

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

[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.

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

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[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 which established the Department. The primary mission of the program is to develop and support the basic research scientists and facilities, and to foster the technical and scientific activities needed to understand the structure and interactions of atomic nuclei, and to understand 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 advise on setting scientific 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 structure of atomic nuclei and the fundamental forces required to hold their constituents in place, 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 Science organizations, act as the Nation's leader in developing standards and management techniques to optimize construction and operations of facilities in a cost effective, safe, and environmentally benign way.
- Leverage United States objectives by means of international cooperation through exchanges of scientists and participation in internationally 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 appropriateness 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 internationally recognized scientific experts. Maintain the highest quality research by taking appropriate corrective management actions based on results of the reviews.
- 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 in scope, costs and schedule of construction projects for world class nuclear physics facilities such as the Relativistic Heavy Ion Collider. 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.
- Review at least 80 percent of the research projects by appropriate peers and selected through a 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 developed for the Scientific User Facility Initiative. Identify participation and contributions by foreign scientists at facilities, and obtain input from user's groups at facilities. Develop appropriate facility funding profiles so as to best provide overall beam availability for the Nuclear Physics program.
- Measure overall program against the scientific priorities recommended in the long range plans that are regularly provided by the DOE/NSF Nuclear Science Advisory Committee (NSAC). Obtain assessments from NSAC and other community forums on the overall direction of the DOE Nuclear Physics program and its coordination with the NSF Nuclear Physics program. Based on this feedback, programmatic changes will be made, where necessary, to assure the Nuclear Physics program is appropriately directed towards highest priority topics in the long range plan.
- Upgrades of scientific facilities will be managed to keep them on schedule and within cost.
- Nuclear Physics will begin the research program at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) in FY 2000.

Significant Accomplishments and Program Shifts

Medium Energy Nuclear Physics

- In FY 2000, operations of the MIT/Bates Linear Accelerator Center facility will be terminated and Decommissioning and Decontamination (D&D) activities will begin.

- All three experimental halls at the Thomas Jefferson National Accelerator Facility are now operational for research. Beams of widely differing energies and currents can be delivered simultaneously to each of the halls to meet the specific requirements of the experiments. The laboratory is now also able to deliver polarized beam to any of the experimental halls.

Heavy Ion Nuclear Physics

- The Relativistic Heavy Ion Collider (RHIC) construction project at Brookhaven National Laboratory (BNL) continues on scope and budget with a completion date of the third Quarter of FY 1999. Fabrication of RHIC detectors, including the additional experimental equipment recommended by NSAC for purposes of particle detection and data analysis, also proceeds on schedule.

  In FY 2000 RHIC initiates its first full year of Operations and its research program will begin with four experiments (STAR, PHENIX, BRAHMS and PHOBOS) involving over 900 researchers and students from 80 institutions and 15 countries. The BNL Tandem/AGS/Booster accelerator complex, which acts as the injector for RHIC, will terminate routine operations of its fixed-target heavy-ion research program.

Low Energy Nuclear Physics

- Construction of the US/Canadian Sudbury Neutrino Observatory (SNO) detector, which sits in a nickel mine 6,800 feet below the surface of the earth, was completed in FY 1998. A dedication of the laboratory was held in Sudbury, Ontario, on May 28, 1998, with Stephen Hawking as one of the speakers. The filling of the region around the detector with water, and the central part of the detector with "heavy water" (D_2O), is now underway and initial measurements using the detector have commenced early in calendar year 1999.
- Gammasphere was moved from the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL) to the ATLAS facility at Argonne National Laboratory (ANL) in FY 1998. A research program at ATLAS was initiated which is focused on the study of the structure of nuclei far from stability utilizing Gammasphere coupled with the existing Fragment Mass Analyzer (FMA). It is now planned that Gammasphere will operate at ATLAS in FY 1999 and move back to the 88-inch Cyclotron in FY 2000.
- The Radioactive Ion Beam (RIB) facility at Oak Ridge National Laboratory (ORNL) successfully developed new beams in FY 1998 and has initiated a series of experiments directed at measuring cross sections important to astrophysics.

Nuclear Theory

- In FY 2000 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 $234,000,000 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 $106,000 and $88,000 for estimated contractor security clearances in FY 1999 and FY 2000, respectively, within the decision unit.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Nuclear Physics					
Medium Energy Nuclear Physics	113,400	118,698	-155	118,543	111,130
Heavy Ion Nuclear Physics	94,736	150,592	-185	150,407	181,810
Low Energy Nuclear Physics	31,872	33,360	-135	33,225	34,170
Nuclear Theory	15,330	15,830	-70	15,760	15,830
Subtotal, Nuclear Physics	255,338	318,480	-545	317,935	342,940
Construction	59,400	16,620	0	16,620	0
Subtotal, Nuclear Physics	314,738	335,100	-545	334,555	342,940
Use of Prior Year Balances	-971 [a]	-776 [a]	0	-776 [a]	0
General Reduction	0	-545	+545	0	0
Total, Nuclear Physics	313,767 [b]	333,779	0	333,779	342,940

Public Law Authorization:

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

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

[b] Excludes $5,660,000 which has been transferred to the SBIR program and $340,000 which has been transferred to the STTR program.

Funding by Site

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	10,783	9,750	10,260	+510	+5.2%
Chicago Operations Office					
Argonne National Laboratory	16,845	16,045	17,485	+1,440	+9.0%
Brookhaven National Laboratory	110,851	115,900	135,549	+19,649	+16.9%
Total, Chicago Operations Office	127,696	131,945	153,034	+21,089	+16.0%
Idaho Operations Office					
Idaho National Engineering Laboratory	90	80	80	0	0.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	21,965	22,118	18,080	-4,038	-18.3%
Lawrence Livermore National Laboratory	845	660	950	+290	+43.9%
Stanford Linear Accelerator Center	9	0	0	0	0.0%
Total, Oakland Operations Office	22,819	22,778	19,030	-3,748	-16.4%
Oak Ridge Operations Office					
Thomas Jefferson National Accelerator Facility	68,850	70,305	73,669	+3,364	+4.8%
Oak Ridge National Laboratory	16,215	15,017	16,665	+1,648	+11.0%
Oak Ridge Institute for Science & Education	719	565	820	+255	+45.1%
Total, Oak Ridge Operations Office	85,784	85,887	91,154	+5,267	+6.1%
All Other Sites [a]	67,566	84,115	69,382	-14,733	-17.5%
Subtotal, Nuclear Physics	314,738	334,555	342,940	+8,385	+2.5%
Use of Prior Year balances	-971 [b]	-776 [b]	0	+776 [b]	+100.0%
Total, Nuclear Physics	313,767	333,779	342,940	+9,161	+2.7%

[a] Funding provided to universities, industry, other federal agencies and other miscellaneous contractors.

[b] 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 (ANL)

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 Isotope Separator On-Line accelerator facility (ISOL); (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 entire Tandem/Booster and Alternating Gradient Synchrotron (AGS) as an injector. RHIC 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 group has been supported to carry out a program of hypernuclear physics and baryon resonance research using proton beams from 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 is also the central U.S. site for the American and international nuclear data and compilation effort. The National Nuclear Data Center is housed at BNL.

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, a program of nuclear data and compilation is supported.

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 at CERN/SPS, BNL/AGS, and RHIC, where they have been major players in the development of the large STAR detector for the new RHIC facility; (3) the Low Energy group, which plays a major role in the construction and implementation 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 the setup and use of the GENIE detector for a program of neutron research using LANSCE beams at Los Alamos National Laboratory. A nuclear data and compilation effort is supported at LLNL.

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) the Liquid Scintillation Neutrino Detector (LSND) experiment which is searching for evidence of neutrino oscillations, and a program of neutron beam research investigating parity violation in nuclei; these activities utilize beams from the LANSCE proton accelerator; (2) a major effort to build components of the PHENIX detector for the new Relativistic Heavy Ion Collider (RHIC) at Brookhaven, as well as to carry out a program of heavy ion research; (3) research is supported to study the quark substructure of the nucleon in experiments at Fermilab, and to plan for the detectors and research for a “spin” physics program at RHIC which will utilize 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 new Radioactive Ion Beam Facility (RIB) 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 new Radioactive Ion Beam Facility (RIB), which is run as a national user facility. RIB allows a program of experimental research investigating a number of issues in astrophysics. Also supported is a heavy ion group which is involved in PHENIX detector development activities for RHIC and the development of the RHIC research program. The theoretical nuclear physics effort at ORNL emphasizes investigations of low energy nuclear structure. Nuclear data and compilation activities are also supported as part of the national nuclear data effort.

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 uses computational tools (i.e. simulations, interactive techniques, remote access to instrumentation for data collection and manipulation), in partnership with educational institutions, for teaching and learning science as it relates to the Office of Science's Nuclear Physics mission.

Thomas Jefferson National Accelerator Facility (TJNAF)

Thomas Jefferson National Accelerator Facility 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 new and 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 research at 83 colleges/universities located in 35 states. This line also includes funding of 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 academic fundamental research, and facility operations and research at electron and proton accelerator facilities at the higher energies of interest to nuclear physics. In addition, the subprogram supports research at accelerators operated by other Department of Energy programs (e.g., High Energy Physics and Basic Energy Sciences) and at other unique domestic or foreign facilities. The research programs are ultimately aimed at achieving an understanding of the structure of the atomic nucleus in terms of the quarks and gluons, the objects which are believed to combine in different ways to make all the other sub-atomic particles. Just as important is the achievement of an understanding of the "strong force", one of only four forces in nature, and the one which 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, investigations of how the properties of protons and neutrons change when imbedded in the nuclear medium, measurements 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 studies of how particles interact with each other inside the nucleus. Two national accelerator facilities are operated entirely under the Medium Energy subprogram - the Thomas Jefferson National Accelerator Facility (TJNAF) in Newport News, Virginia, operated by the Southeastern Universities Research Association and the Bates Linear Accelerator Center in Middleton, Massachusetts, 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 planned research program at the new TJNAF, for example, involves 600 scientists from 17 foreign countries; 81 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. Nuclear Physics will provide opportunities for college faculty and students to spend time at DOE laboratories, to participate in world-class research projects. Faculty/Student Science Teams will visit our DOE Laboratories during the academic summer/semesters, be involved in conducting research, writing proposals, utilizing technology and pursuing technical or scientific careers. Primary goals of the Science Teams are to build long-term partnerships among DOE laboratories and provide faculty/students with a deeper understanding of DOE science associated needs for research and development. Funds will be provided to pay for faculty/student stipends, travel, housing and subsidize laboratory scientists' time for this activity ($973,000).

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Research					
University Research	16,080	17,085	15,662	-1,423	-8.3%
National Laboratory Research	19,713	20,124	19,985	-139	-0.7%
Other Research	987	6,064	5,748	-316	-5.2%
Subtotal, Research	36,780	43,273	41,395	-1,878	-4.3%
Operations					
TJNAF Operations	62,720	64,170	67,235	+3,065	+4.8%
Bates Operations	13,550	10,800	2,500	-8,300	-76.9%
Other Operations	350	300	0	-300	-100.0%
Subtotal, Operations	76,620	75,270	69,735	-5,535	-7.4%
Total, Medium Energy Nuclear Physics	113,400	118,543	111,130	-7,413	-6.3%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000

Research

University Research

These activities comprise a broad program of research, and includes 40 grants at 32 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 "Bates Research" is 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 MIT activities which are not carried out at Bates.

- **Bates Research:** At the MIT/Bates accelerator, university researchers have been carrying out "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 Experimental Hall on the proton, deuteron, and complex nuclei including measurements of the transition of the proton to its excited state.
  - In FY 1999, important measurements will be completed in a limited experimental program.

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
▸ In FY 2000, the Bates accelerator will terminate operations. Supported MIT scientists will transition to other research facilities.	2,900	4,600	1,500
■ **Other University Research:**			
▸ University scientists are collaborating on important ongoing and future experiments at TJNAF. In FY 2000 activities include studies of the charge structure of the neutron in Hall C, planned measurements of 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 are already underway.			
▸ A number of university groups are collaborating in experiments using the new out-of-plane spectrometers in the South Experimental Hall at the Bates Laboratory. In FY 2000 Bates will cease operations; MIT and other university scientists will transition to other research facilities. Part of the Bates research funds are being added to other university research to support this transition.			
▸ University scientists and National Laboratory collaborators will continue to carry out the HERMES experiment at the DESY laboratory in Hamburg, Germany. This experiment will measure what components of the proton or neutron determine the "spin" of these particles, an important and timely scientific issue. In FY 2000, HERMES will utilize a new Ring Imaging Cerenkov counter for particle identification.			
▸ A new underground neutrino detector in Arizona is beginning a search for neutrino oscillations using the Palo Verde nuclear power reactors as the source of neutrinos. If neutrino oscillations are observed, implying neutrinos have mass, there would be a major impact on our understanding of the laws of physics. In FY 2000, the program will be completing its data-taking phase, and analysis will be underway.	13,180	12,485	14,162
Total, University Research	16,080	17,085	15,662

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000

National Laboratory Research

Included is: (1) the research supported at the Thomas Jefferson National Accelerator Facility, which houses the Nation's new and 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:**
  - Scientists at TJNAF, with support of the user community, have completed assembly of new experimental apparatus for Halls A, B, and C. All three experimental Halls are now 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.
  - Eight experiments have been completed in Hall C. Experimental equipment in Hall A is complete and the experimental program is underway. Four experiments have completed data accumulation in Hall A. The complex large-acceptance spectrometer in Hall B has been completed and the research program is now underway. One experiment has been completed. In FY 2000, the experimental program will run routinely in all three Halls.
  - Capital equipment funding will be provided for assembling and installing polarized electron injector improvements for the accelerator. Capital equipment funds will be used to install ancillary equipment items such as polarized targets for experimental Halls A, B, and C spectrometer systems, complete a major upgrade of the data reduction system to handle massive amounts of raw data, and to continue fabrication of second generation experiments such as a spectrometer that is designed to investigate the strange quark content of the proton. . . . .

	FY 1998	FY 1999	FY 2000
quark content of the proton	5,600	5,600	5,700

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **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, scientists at the Alternating Gradient Synchrotron have been working with university researchers on experiments to look at the behavior of strange quarks in nuclei, and other work has been investigating the spectroscopy of strongly interacting particles. These efforts involve large detectors which were recently moved from Los Alamos and the Stanford Linear Accelerator Center. In FY 2000, efforts involving analysis of data obtained in prior years will be supported. The AGS will be primarily utilized as an injector for the new Relativistic Heavy Ion Collider (RHIC).			
▸ Also at Brookhaven, Laser Electron Gamma Source (LEGS) scientists are developing a new spectrometer and polarized target for a new program of spin physics. 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 2000, the research program utilizing the new equipment, will be fully underway.			
▸ At Los Alamos National Laboratory, scientists and collaborators may continue to carry out highly interesting but controversial measurements in search of neutrino oscillations. If oscillations are found, then neutrinos would have mass, in disagreement with our present understanding of the laws of physics.			
▸ Los Alamos National Laboratory scientists and collaborators are also developing detectors for the Relativistic Heavy Ion Collider which will enable use of polarized protons and which builds upon an experiment to measure the quark structure of the proton at Fermilab. . .	14,113	14,524	14,285
Total, National Laboratory Research	19,713	20,124	19,985

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000

Other Research

- **SBIR/STTR:** Amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs and other established obligations which the Medium Energy Nuclear Physics subprogram must meet.
  - In FY 1998 $4,165,000 and $340,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs. . . . . .

	FY 1998	FY 1999	FY 2000
SBIR/STTR	987	6,064	5,748
Total, Research	36,780	43,273	41,395

Operations

TJNAF Operations

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

- **TJNAF Accelerator Operations:**
  - The accelerator is now capable of delivering beams of differing energies and currents simultaneously to the three experimental halls. Polarized beam capability is now also available and is being used for experiments.

	(hours of beam for research)		
	FY 1998	FY 1999	FY 2000
TJNAF	4,500	4,500	4,500

  - AIP funding will provide for polarized injector and beam handling components which 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. 39,755 41,200 43,360

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
■ **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.	22,965	22,970	23,875
Total, TJNAF Operations	62,720	64,170	67,235

Bates Operations

- Funding is provided to support accelerator operations at the MIT/Bates Linear Accelerator Center.
  - Bates operations will terminate in FY 2000. Funding is provided for Decommissioning and Decontamination activities.

	(hours of beam for research)		
	FY 1998	FY 1999	FY 2000
Bates	2,000	1,000	0

	FY 1998	FY 1999	FY 2000
▸ Accelerator operations in FY 1998 provided beams for the research programs in the North and South Halls, for testing of internal continuous beams in the South Hall Ring, and for development of extracted continuous beams for delivery to the existing South Hall spectrometers.			
▸ AIP funding has supported additions and modifications to the accelerator facilities; GPP funding has provided for minor new construction and utility systems. No AIP/GPP will be provided in FY 2000.	13,550	10,800	2,500
Other Operations			
■ This category includes facility operations funding at other facilities when the importance of the science justifies the partial support of another research facility.			
▸ No operations support of other facilities is planned in FY 2000.	350	300	0
Total, Operations	76,620	75,270	69,735
Total, Medium Energy Nuclear Physics	113,400	118,543	111,130

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Research	
■ **University Research**	
▸ Since Bates facility operations will be terminated in FY 2000, Bates research has been reduced allowing for completion of data analysis only. MIT scientists will transition to other nuclear physics facilities	-3,100
▸ Other university research is increased by the addition of part of the Bates research funds, since a number of the MIT scientists will transfer their research efforts to other facilities.	+1,677
Total, University Research	-1,423
■ **National Laboratory Research**	
▸ TJNAF research support is increased to maintain level of TJNAF scientists in experimental research.	+100
▸ Other National Laboratory research is slightly reduced	-239
Total, National Laboratory Research	-139
■ **Other Research**	
▸ Estimated SBIR/STTR obligations decrease slightly.	-316
Total Research	-1,878
Operations	
■ **TJNAF Operations**	
▸ Funding for the Thomas Jefferson National Accelerator Facility operations is increased to cover increased cost of experiments and cost of living increases.	+2,160
▸ TJNAF experimental support is increased to provide more effective and efficient experimental setup and disassembly to improve scientific output.	+905
Total, TJNAF Operations	+3,065
■ **Bates Operations**	
▸ The MIT/Bates Linear Accelerator Center will cease operations. All planned Capital Equipment, AIP, and GPP funding has been eliminated	-8,300
■ **Other Operations**	
▸ No operations support of other facilities is expected in FY 2000.	-300
Total, Operations	-5,535
Total Funding Change, Medium Energy Nuclear Physics	-7,413

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 which are only gently excited (cool nuclear matter), but taken to their limits of deformation and isotopic stability. With higher energy heavy-ion beams it is possible to study highly excited nuclei (warm nuclear matter) which, when sufficiently heated, are expected to vaporize in a process analogous to the liquid-gas phase transition of heated water. At relativistic bombarding energies the properties of hot**,** dense nuclear matter are studied with a 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 on Department of Energy (DOE) supported facilities, as well as on 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 Berkeley) for these studies. The Relativistic Heavy Ion Collider (RHIC), under construction at Brookhaven National Laboratory since FY 1991, is scheduled to begin operations in the 4th Quarter of FY 1999, initiating a high-priority research program addressing fundamental questions about the nature of nuclear matter. In FY 2000 resources will be directed towards initiating RHIC's research program in its first full year of operation. 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, for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems, for the Brookhaven National Laboratory (BNL) as part of Nuclear Physics' landlord responsibilities for this laboratory.

Performance Measures

- Nuclear Physics will begin the research program at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) in FY 2000.

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Research					
University Research	17,197	16,685	16,965	+280	+1.7%
National Laboratory Research	35,178	38,425	33,450	-4,975	-12.9%
Other Research	86	2,505	2,808	+303	+12.1%
Subtotal, Research	52,461	57,615	53,223	-4,392	-7.6%
Operations					
RHIC Operations	25,520	74,800	106,100	+31,300	+41.8%
National Laboratory Facility Operations	10,805	12,542	13,127	+585	+4.7%
Other Operations	5,950	5,450	9,360	+3,910	+71.7%
Subtotal, Operations	42,275	92,792	128,587	+35,795	+38.6%
Total, Heavy Ion Nuclear Physics	94,736	150,407	181,810	+31,403	+20.9%

Detailed Program Justifications

(dollars in thousands)		
FY 1998	FY 1999	FY 2000

Research

University Research

Support is provided for the research of scientists and students from over 30 universities.

- 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 with priorities on the initial experiments at RHIC where an entirely new regime of nuclear matter will become available for study for the first time. University researchers are involved in all aspects (construction, installation and operation) of the four detector systems (STAR, PHENIX, BRAHMS, and PHOBOS) at RHIC.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ 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 the Gammasphere and Fragment Mass Analyzer Detectors with beams from the ATLAS and 88-inch Cyclotron facilities and complementary studies using the smaller university facilities (Yale and Texas A&M) whose in-house research programs also include an emphasis on student training.	17,197	16,685	16,965
National Laboratory Research			
Support is provided for the research programs of scientists at five National Laboratories (ANL, BNL, LBNL, LANL and ORNL).			
■ **BNL RHIC Research:** Laboratory researchers at BNL play a major role in planning and carrying out the research on the four experiments (STAR, PHENIX, BRAHMS and PHOBOS) at RHIC and have major responsibilities for maintaining, improving and developing this instrumentation for use by the user community. Activities will be focused on initiating a research program in the first full year of RHIC operations. FY 2000 will be a critical year involving continued integration of many different subsystems in the four RHIC detectors to facilitate the beginning of studies of the expected new forms of nuclear matter that will be created in heavy ion collisions at RHIC. The priority for the capital equipment included in this funding is on additional experimental equipment for RHIC, (see Major Items of Equipment) which includes a start in FY 2000 of the Electromagnetic Calorimeter enhancement for STAR whose preliminary TEC is about $5 million. This has been recommended in a NSAC review as important to enhance the physics objectives of the RHIC program. Included are funds for computing for off-line analysis, and enhancements to the baseline STAR and PHENIX detectors that address new physics.	15,247	17,870	12,400

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Other National Laboratory Research:** Laboratory researchers associated with accelerator facilities at ANL (ATLAS) and LBNL (88-inch Cyclotron) have major responsibilities for maintaining, improving and developing instrumentation for use by the user community at their facilities, as well as playing important roles in carrying out research that address the Program's priorities. Activities will be focused on studies of the properties of short-lived nuclei using specialized instrumentation, studies of nuclear structure with Gammasphere and R&D efforts for the proposed next generation Isotopic Separation On-Line (ISOL) facility for radioactive beams. Researchers at LANL, LBNL, and ORNL will utilize their laboratory competencies in undertaking R&D, management and construction responsibilities for major initiatives such as RHIC detectors (e.g., STAR and PHENIX) and play leadership roles in carrying out research utilizing them. Activities will be focused on initiating a research program in the first full year of RHIC operations. The priorities for capital equipment in this funding are for support for the ongoing research activities at the supported accelerator facilities.	19,931	20,555	21,050
Total, National Laboratory Research	35,178	38,425	33,450
Other Research			
■ Amounts shown are the estimated requirements for the continuation of the SBIR and STTR programs and other established obligations. In FY 1998 $695,000 was transferred to the SBIR program. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	86	2,505	2,808
Total, Heavy Ion Nuclear Physics Research	52,461	57,615	53,223

Operations

RHIC Operations

■ The RHIC Project is scheduled to be completed in the 3rd Quarter with commissioning operations beginning in the 4th Quarter of FY 1999. RHIC will be a unique facility whose colliding relativistic heavy ion beams will permit exploration of hot, dense nuclear matter and recreate the transition from

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
quarks to nucleons which 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 which up to now has only been studied theoretically.			
▸ **RHIC/AGS Accelerator Operations:** Support is provided for the operation, maintenance, improvement and enhancement of the RHIC accelerator complex. The RHIC complex includes the Tandem/AGS facility whose fixed-target heavy-ion research program will be terminated in FY 2000 and which will serve as the injector for RHIC. RHIC will begin its first full year of operations with a 33 week running schedule and the goal of 22 weeks (3,300 hours) for research and 11 weeks for accelerator studies. .	25,520	66,800	76,675

	(hours of beam for research)		
	FY 1998	FY 1999	FY 2000
AGS	672	0	0
RHIC	0	500	3,300

▸ **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 will initiate its research program in FY 2000 with four experimental detectors (STAR, PHENIX, BRAHMS and PHOBOS). Approximately 1,000 scientists and students from 81 institutions and 15 countries will participate in the research programs of these four experiments.	0	8,000	29,425
Total, RHIC Operations	25,520	74,800	106,100

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.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
▸ Support is provided for the operation, maintenance, improvement and enhancement of the ATLAS and 88-inch Cyclotron accelerator facilities. FY 2000 ATLAS and 88-inch operations funding (and beam hours shown below) reflect the move of the Gammasphere program back to the 88-inch Cyclotron and the continued development of radioactive beam capabilities at ATLAS. These facilities are planned to provide yearly hours of beam for research as indicated below. In FY 2000 each facility will carry out about 40 experiments conducted by about 270 researchers.			

	(hours of beam for research)		
	FY 1998	FY 1999	FY 2000
ATLAS	5,700	5,700	5,300
88-inch Cyclotron	4,500	4,500	5,500

	FY 1998	FY 1999	FY 2000
▸ Accelerator Improvement Project (AIP) funds and capital equipment are provided for the maintenance and upgrade of these facilities.	10,805	12,542	13,127
Other Operations			
■ **GPP/GPE:** GPP funding will be provided for minor new construction, other capital alterations and additions, and for buildings and utility systems at Brookhaven National Laboratory (BNL). 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 this type of project 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.	5,950	5,450	9,360
Total, Operations	42,275	92,792	128,587
Total, Heavy Ion Nuclear Physics	94,736	150,407	181,810

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Research	
■ **University Research**	
▸ FY 2000 funding for University Research provides for almost constant effort compared to FY 1999 for research and educational activities.	+280
■ **National Laboratory Research**	
▸ The $3,000,000 of FY 1999 funding provided for experimental support for RHIC detector and computer efforts is shifted in FY 2000 to RHIC Experimental Support Operations. The plans made early in the project to procure computing equipment just prior to operations to secure the most powerful and up-to-date system at the lowest cost, are on schedule. In FY 2000 about $2,500,000 of the capital equipment funding provided in FY 1999 for RHIC computing and experimental equipment projects which expand RHIC scientific capabilities are shifted to RHIC Experimental Support Operations. The buildup of scientific and technical support and infrastructure needed for the RHIC detectors when they become operational in FY 2000, was supported in research in the years preceding the start of RHIC operations. This manpower and infrastructure belongs in RHIC Experimental Support and Operations in FY 2000. FY 2000 operating funding for research at National Laboratories other than BNL is up about $500,000 when compared with FY 1999 and distributed with emphasis on enhanced support for R&D efforts directed towards issues relevant to the proposed ISOL facility for radioactive beams.	-4,975
■ **Other Research**	
▸ Estimated funding for SBIR and other obligations increases from FY 1999. . . .	+303
Total, Research	-4,392
Operations	
■ **RHIC Operations**	
▸ First full year of RHIC operations commences. FY 1999 RHIC Construction funds of $16,620,000 are redirected to Operations. Approximately $5,500,000 of funds provided in FY 1999 to BNL RHIC Research for experimental support activities in preparation of start of RHIC Operations are transferred in FY 2000 to RHIC Operations. The FY 2000 funding provides for an estimated 33 week running schedule	+31,300

	FY 2000 vs. FY 1999 ($000)
■ **National Laboratory Facility Operations**	
▸ In FY 2000 funding for operations of the 88-Inch Cyclotron facility is increased to provide more beam hours for Gammasphere after its arrival from ATLAS. ATLAS operation will be slightly less than the FY 1999 level of effort.	+585
■ **Other Operations**	
▸ With the beginning of RHIC operations the program assumes landlord responsibility for providing general plant projects (GPP) and general purpose equipment (GPE) at BNL and ceases these responsibilities at LBNL.	+3,910
Total, Operations	+35,795
Total Funding Change, Heavy Ion Nuclear Physics	+31,403

Low Energy Nuclear Physics

Mission Supporting Goals and Objectives

The Low Energy Nuclear Physics subprogram supports research directed at addressing issues in nuclear astrophysics, the understanding of the behavior of nucleons at the surface of the nucleus as well as the collective behavior of the entire ensemble of nucleons acting in concert; nuclear reaction mechanisms; and experimental tests of fundamental symmetries. 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. 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. Included in this subprogram are the activities of the National Nuclear Data Center and its support sites 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.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
University Research	9,447	9,810	10,050	+240	+2.4%
National Laboratory Research	8,468	8,770	8,725	-45	-0.5%
Nuclear Data	5,096	4,900	5,000	+100	+2.0%
RIB Operations	8,840	8,630	9,250	+620	+7.2%
Other	21	1,115	1,145	+30	+2.7%
Total, Low Energy Nuclear Physics	31,872	33,225	34,170	+945	+2.8%

Detailed Program Justifications

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
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. The support level for this activity is determined by juxtaposing the peer review assessment of the worth and priority of the project with the researchers request for the number of graduate students, postdoctoral fellows, other staff and necessary items to complete the proposed work.			
■ 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 and neutron physics 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 fundamental issues essential to the long term goal of understanding the production and constituents of stars.	9,447	9,810	10,050

National Laboratory Research

- **Radioactive Ion Beam Facility Research:**
  - The RIB facility will focus mainly on nuclear astrophysics problems bearing on the creation of the elements and nuclear properties with extreme proton/neutron ratios.
  - Installation of the Daresbury Recoil Separator, a $2,000,000 device contributed by the United Kingdom, allows separation of the products of nuclear reactions from particles a trillion times more intense, enabling the measurement of nuclear reactions that fuel the explosion of stars.
  - Capital equipment funds are provided to expand the list of available beam species.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
▸ There will be an increased level of effort dedicated to research and development leading to an advanced RIB facility.	5,313	4,615	5,400
■ **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 that holds 1,000 tons of heavy water that is the solar neutrino detector. The SNO laboratory is located 6,800 feet underground. The detector water fill will be completed in FY 1999 and data taking will start. The level of SNO support at the national laboratories is at a continuing level of effort that allows the systematic and efficient collection and analysis of data.			
▸ The research that follows after the completion of filling the tank will determine whether the observed dearth of solar neutrinos results from unexpected properties of the sun, or whether it results from a fundamental new property of neutrinos—namely that neutrinos produced in radioactive decay change their nature during the time it takes them to reach the earth from the sun.			
▸ Capital equipment funds were used to construct and transport special rare gas Helium-3 neutron counters (800m total length) to their underground storage in the ultra low cosmic ray background environment of the SNO mine. They are being stored for a period of time which is sufficient to allow decay to low levels of the radioactivity induced in the detectors by the above ground cosmic ray background.	3,155	4,155	3,325
Total, National Laboratory Research	8,468	8,770	8,725

Nuclear Data

- This is a service function of the Nuclear Physics program which collects, evaluates, stores, and disseminates nuclear information. Its single national and international center point is the United States National Nuclear Data Center (US-NNDC) at Brookhaven National Laboratory. The level of effort is at an ongoing level and was peer reviewed by a panel of experts that addressed the activity level.

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
■ The NNDC uses 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 scientists, reports to and supports the NNDC in data evaluation and development of on-line access capabilities.			
■ After completion of a review, a new activity, jointly supported with the Nuclear Physics research community, was established in order to serve the nuclear astrophysics community. This will be a joint activity between the US-NNDC and a consortium of researchers and data scientists. This new project, whose level of activity was established by user demand and input, will be an ongoing activity of the Data program.	5,096	4,900	5,000

RIB Operations

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

	FY 1998	FY 1999	FY 2000
	(hours of beam for research)		
RIB	2,200	2,400	2,400

■ Research at the Oak Ridge Electron Linear Accelerator (ORELA), which 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.			
■ This technically difficult project, which couples the existing cyclotron and tandem accelerators, was fully operational in FY 1998, and now is operating with radioactive ion beams of arsenic and fluorine as well as beams of Nickel-56.	8,840	8,630	9,250

Other

■ Amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs. The Lawrence and Fermi Awards which are funded under this line, provide annual monetary awards to honorees selected by the Department of Energy for their outstanding contributions to nuclear science.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **SBIR/STTR:** In FY 1998 $800,000 was transferred to the SBIR program. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	21	1,115	1,145
Total, Low Energy Nuclear Physics	31,872	33,225	34,170

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ **University Research**	
▸ Research associated with RIB experiments and nuclear astrophysics research activities will increase while SNO construction activities will be completed. . . .	+240
■ **National Laboratory Research**	
▸ Increased research in high priority nuclear astrophysics measurements will replace a diminished activity in solar neutrino research.	-45
■ **Nuclear Data**	
▸ Support will increase for activities to provide data and services on-line to replace data and services previously supplied in hard copy.	+100
■ **RIB Operations**	
▸ RIB operations will be maintained with a cost-of-living increase thereby providing a constant amount of beam time.	+620
■ **Other**	
▸ Estimated FY 2000 funds for SBIR increase compared to FY 1999.	+30
Total Funding Change, Low Energy Nuclear Physics	+945

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 interaction 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. The Institute is a seedbed for new collaborations, ideas, and directions in nuclear physics.

Significant progress has been made in the past year. Three examples of particular accomplishments in that period are: (1) University theorists made a significant step forward in our understanding of how and where the heavier elements observed in nature were originally produced, producing strong evidence that they were produced in neutron rich gas at the core of supernova explosions. (2) 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 soon to be operating Relativistic Heavy Ion Collider facility at the Brookhaven National Laboratory. In the past year, several new and potentially clear signals of the creation of the quark-gluon plasma in such collisions were suggested by these models. (3) 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.

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 1998	FY 1999	FY 2000	$ Change	% Change
University Research	9,974	10,464	10,510	+46	+0.4%
National Laboratory Research	5,356	5,296	5,320	+24	+0.5%
Total, Nuclear Theory	15,330	15,760	15,830	+70	+0.4%

Detailed Program Justifications

(dollars in thousands)	FY 1998	FY 1999	FY 2000

University Research

- Research is conducted through individual grants to faculty at roughly 50 universities.
- The range of topics studied through these grants is broad, and each of the active areas of experimental nuclear physics is supported by at least some of the nuclear theory grants.
- 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, the 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. . . . . 9,974 10,464 10,510

National Laboratory Research

- Through this activity, small groups of theoretical nuclear physicists 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 1998	FY 1999	FY 2000
■ 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.	5,356	5,296	5,320
Total, Nuclear Theory	15,330	15,760	15,830

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ **University Research**	
▸ Continue program at slightly reduced level of effort, consistent with less than cost-of-living increase in funding.	+46
■ **National Laboratory Research**	
▸ Continue program at slightly reduced level of effort, consistent with less than cost-of-living increase in funding.	+24
Total Funding Change, Nuclear Theory	+70

Capital Operating Expense and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
General Plant Projects	4,610	4,000	5,655	+1,655	+41.4%
Accelerator Improvement Projects	4,200	4,900	3,900	-1,000	-20.4%
Capital Equipment	26,110	29,586	30,355	+769	+2.6%
Total, Capital Operating Expense	34,920	38,486	39,910	+1,424	+3.7%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1998	FY 1999	FY 2000	Accept-ance Date
STAR Silicon Vertex Tracker	7,000	3,450	1,500	1,300	750	FY 2000
PHENIX Muon Arm Instrumentation	11,400	3,375	2,800	2,400	2,525	FY 2001
Analysis System for RHIC Detectors	7,900	775	2,000	3,600	1,525	FY 1999
BLAST Large Acceptance Detector	4,900	400	900	900	0	TBD
STAR EM Calorimeter	TBD [a]	0	0	0	1,800	FY 2002
Total, Major Items of Equipment		8,000	7,200	8,200	6,600	

[a] Preliminary TEC is estimated to be about $5 million.

Biological and Environmental Research

Program Mission

The Biological and Environmental Research (BER) program mission – For over 50 years BER has been investing to advance environmental and biomedical knowledge connected to energy. The BER 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, and anticipate 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 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 this 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 Global Environmental Change* — Acquire the data and develop the understanding necessary to predict how energy production and use can affect the global and regional environment.

Performance Measures

The quality and appropriateness of the Biological and Environmental Research (BER) program and 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 conferences and workshops, and by awards received by BER-supported researchers. Progress in the field is also routinely compared to the scientific priorities recommended by the Biological and Environmental Research Advisory Committee 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 Human Genome Program and the Global Change Research Program. In addition to panel reviews that evaluate and select individual projects and programmatic reviews by the chartered Biological and Environmental Research Advisory Committee, 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. Blue ribbon panels 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 panels 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 at reasonable costs.

Specific BER program performance measures are:

- Excellence in basic research: At least 80 percent of the research projects will be reviewed by appropriate peers and selected through a merit-based competitive process.
- Access to Human Genome research results: BER will complete sequencing of 50 million finished and 70 million high quality draft subunits of human DNA to submit to publicly accessible databases in FY 2000.
- Microbial Genomics: BER will complete the genetic sequencing of over 10 additional microbes with significant potential for waste cleanup and energy production.

- Discovering new biological structures with more than 60 percent of them published in the peer reviewed literature resulting from data generated at synchrotron user stations served by the BER structural biology support facilities program.

- Progress in Boron Neutron Capture Therapy (BNCT) Research: Phase I clinical trials of BNCT at reactor sources of neutrons will be completed for at least 100 patients, and research on a facility for 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.

- Atmospheric Radiation Measurement (ARM) accomplishments: BER will conduct five intensive operations periods at the ARM Southern Great Plains site. Data will be obtained from the second station on the North Slope of Alaska. The third station in the Tropical Western Pacific, on Christmas Island, will become operational.

- Work will proceed on the development of the next generation coupled ocean-atmosphere climate model, leading to better information for assessing climate change and variability at regional, rather than global scales. This next generation model will change grid size from the current 300-500 kilometers on a side to less than 200 kilometers on a side.

- Twenty-five AmeriFlux sites representing major types of ecosystem types and land uses in North and Central America, including forests, croplands, grasslands, rangelands and tundra ecosystems, will be operating and collecting data that will allow inter-site comparisons of (1) the atmosphere-terrestrial biosphere exchange of energy and water, (2) the net sequestration of carbon dioxide, (3) the effects of environmental factors such as climate variation on the net exchange of carbon, and (4) the role of biophysical process controlling this exchange. AmeriFlux is a network of instrumented research tower sites designed to provide consistent, quality assured, documented long-term measurements of carbon exchange between the atmosphere and terrestrial biosphere. These measurements are necessary to define the current global carbon dioxide budget, enable improved 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.

- Develop and implement, in cooperation with Basic Energy Sciences, a comprehensive program within the Climate Change Technology Initiative, where the focus areas are those that promise the maximum impact in the area of carbon management in addition to supporting fundamental research that addresses other diverse aspects of the problem.

- Coordinate with other federal agencies, Canada, and Brazil to maximize national and international capabilites to enhance understanding of the current global carbon dioxide distribution and the role of the terrestrial biosphere in that distribution.

- Develop collaborative partnerships between strong marine sciences research institutions and those with developing capabilities to advance innovative techniques in modern molecular biology to understand the coupling between carbon and nitrogen cycles in coastal waters and sediments.

- In cooperation with NASA, NSF, USDA/Forest Service, and the Smithsonian Institution, provide quantitative data on the annual exchange of carbon dioxide between the atmosphere and terrestrial ecosystem from 25 AmeriFlux sites representing major types of ecosystem and land uses in North

Central America. Provide data on both the effects of environmental factors, such as climate variation, on the net sequestration or release of carbon dioxide and the role of biophysical processes controlling the net exchange.

- Environmental remediation developments: The Natural and Accelerated Bioremediation Research (NABIR) program will continue to support fundamental research in environmental and molecular sciences that will underpin the development of bioremediation for containing hazardous waste and cleaning DOE sites. Site characterization of the first NABIR Field Research Center will proceed, and activities necessary to enable research sample distribution to investigators will commence.
- The William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) will be identified and cited as an important resource in research publications and research proposals written by investigators in academia and at National Laboratories.
- 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.
- Education accomplishments: The educational activities in the Global Change Research Program will continue to focus on bringing knowledge about the scientific questions and research needs surrounding global environmental change to students at the undergraduate and graduate levels, with an emphasis on DOE mission areas in global change research. Included in these activities are the Summer Undergraduate Research Experience, Graduate Research Environmental Fellowships, and participation in the multi-agency "Significant Opportunities in Atmospheric Research and Science" Program.
- Education accomplishments: Continuing to make 4 to 10 appointments each in the BER Alexander Hollaender Distinguished Post Doctoral Fellowship Program; and the Historical Black Colleges and Universities Faculty and Student Research Programs.

Significant Accomplishments and Program Shifts

Life Sciences

- **TIGR Takes the World of Biology by the Tail** - Three of the hottest eleven papers in biology in 1997 were published by DOE-funded scientist Craig Venter, the president of The Institute for Genomic Research (TIGR). The papers described the complete genomic sequencing of microbes, two of which were funded by the BER Microbial Genome Program. The impact these papers are having emphasizes one of the central principles of both the human and microbial genome programs, that complete genome sequences yield answers to fundamental questions in biology.
- **DOE Joint Genome Institute Second Leading U.S. Producer of DNA Sequence** - In only its first full year of operation, the DOE Joint Genome Institute (JGI) has set ambitious DNA sequencing goals based on international standards for DNA sequence quality. In FY 1998, the JGI became the second leading producer of high quality human DNA sequence among U.S. sequencing

centers. The JGI's monthly sequencing goals and progress are available to the entire scientific community at the JGI Web site, http://www.jgi.doe.gov/Docs/JGI_Seq_Summary.html.

DOE's Bold Human DNA Sequencing Scale Up:

Sequences Submitted to Public Database

FY 1998 Actual	FY 1999 Estimate	FY 2000 Estimate
21,000,000 finished	30,000,000 finished	50,000,000 finished
	40,000,000 draft	70,000,000 draft

The Human Genome Program (HGP) was initiated by the Department of Energy (DOE) in 1986 to map and determine the complete DNA sequence of the human genome. The principal goal of this international program is to determine a representative human DNA sequence of all 3 billion base pairs in the human genome. A Memorandum of Understanding was established with the National Institutes of Health (NIH) in 1988 to coordinate the U.S. Genome Project with the international efforts. The new 5 year plan, developed in 1998, calls for determining a draft sequence by FY 2001 and the complete finished sequence of the human genome by the year 2003. The U.S. is responsible for producing approximately 65 percent of the sequence information. The Department of Energy is sequencing 10-14 percent of the genome, a quantity that is proportional to its budget, with NIH responsible for the balance of the U.S. effort.

- **DNA Replication Uncovered** - A team of BER-funded Harvard Medical School researchers have established the 3 dimensional, atom-by-atom structure of an enzyme system responsible for DNA replication. The core enzyme, T7 DNA polymerase, has long been used as a key reagent for determining the sequence of DNA. This work contributes to the development of improved resources and technologies for microbial, human, and other genome sequencing projects and will aid in the rational design of antiviral regimens, whose DNA replication systems are promising targets for drug intervention.

- **Game of 20 Questions (Actually 30) May Speed Hunt for Disease-Causing Genes** - A new research tool, developed at the University of Southern California (USC) by molecular biologist Dr. Norman Arnheim and mathematician Dr. Pavel Pevzner, promises to speed the hunt for disease-causing genes. By using a new technique that resembles a game of "20 Questions," genes can be found buried in human chromosomes in large volumes of so-called "junk DNA" that does not carry information for specific protein products. This new tool has direct applications for research into genetically based human disease.

- **DOE Human Subjects Research Database for FY 1997 on the Web** - The DOE's Human Subjects Research Database (HSRD) has been updated for FY 1997 and is publicly accessible 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 252 research projects at 31 facilities, involving the use of human subjects that are supported by DOE or conducted at DOE facilities, ranging from actual experimentation to simple questionnaires.

- **Kidney Disease Gene Discovered with Help of Livermore Scientists** - DOE's investment in building a highly detailed human genetic roadmap for Chromosome 19 is paying off. Lawrence Livermore National Laboratory scientists have teamed with international collaborators in Sweden and Finland to pinpoint the location of a gene on Chromosome 19 that causes congenital nephrotic syndrome, a deadly kidney disease. The disease usually leads to death by age 2 striking about one in 10,000 Finnish children. The discovery has led to a diagnostic tool to test for the gene in parents who may be carriers of the disease and may be a key to understanding how the human kidney filtration process works.

- **Next Generation of Genome Instrumentation -** The genome instrumentation research subprogram that supported basic research leading to widely used gene sequencing methods in capillary electrophoresis and mass spectrometry has been redirected to target needs of genomic science after the completion of the first human genome sequence.

- **New Light on Molecules** - Development of an experimental station for soft x-ray spectroscopy of biologically important molecules is completed at the Advanced Light Source and initial experiments are carried out to evaluate the power of this technology in elucidating biological structures.

- **Genomic Contributions to CCTI** - The BER microbial genome program has made significant investments in the technology that enables genome sequencing at rates previously unattainable. Capitalizing on these investments, the genomes of microbes that produce methane and hydrogen will be sequenced as part of the first awards under the Climate Change Technology Initiative (CCTI). This will enable the identification of the key genetic components of the organisms that regulate the production of these gases. The search for new fuel sources is a key element of a more comprehensive carbon management program. Planning for joint CCTI-related activities with the Office of Fossil Energy was initiated.

Environmental Processes

- **Data on Arctic Ocean Provided** - 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. The ARM equipment used during the SHEBA campaign will be modified and redeployed on the North Slope of Alaska in 1999.

- **Looking at Clouds from Both Sides** - The joint ARM-UAV and NASA study of tropical cirrus clouds will have been completed, providing new information on key cloud formations that moderate the radiation budget of the Earth in 1999.

- **Island Effects on Clouds** - The ARM-led, multi-agency and Japanese experimental campaign on Nauru (Tropical Western Pacific) will have obtained new data on the effects of islands in measuring solar radiation and cloud interactions with the oceans in 1999.

- **Lead Role for ARM** - In response to a request from the World Climate Research Program's Global Energy and Water Cycle Experiment (GEWEX) Water Vapor Project, ARM assumed the lead role in developing guidelines for GEWEX observation and data management of this international program.

- **Variance Among Models Decreases -** The Program for Climate Model Diagnosis and Intercomparison continued to be the world's most authoritative effort in analyzing improvements in global climate models with virtually all climate modelers in the world participating. Analysis of the output from 11 different coupled ocean/atmosphere climate models, using a common scenario for increasing atmospheric carbon dioxide, has found that nearly all of the models calculate similar magnitudes for global average warming--about 2 degrees Celsius at the time that carbon dioxide doubles. This is in contrast to earlier studies that found considerable variance among model predictions.

- **More FACTS -** The first phase of the Forest Atmosphere Carbon Transfer and Storage (FACTS-1) experiment was completed. Located in the Duke Forest and developed as a joint effort between Brookhaven National Laboratory and Duke University, FACTS-1 is the first fully operational forest Free Air Carbon Dioxide Enrichment experiment. Data obtained during this phase will be analyzed to provide systematic data necessary to predict the quantity of carbon sequestered by forest vegetation and to understand the response of forest systems when exposed to elevated atmospheric carbon dioxide concentrations.

- **Changing Interannual Variation in Precipitation Impacts Forest Growth** - Experiments at the Throughput Displacement Experiment at the Walker Branch Watershed, Oak Ridge, Tennessee, suggested that if climate change resulted in a 30 percent decline in precipitation, it would alter the regeneration and species composition of deciduous forests in the southeastern U.S. Data also suggest that changes in interannual variation in precipitation, such as increases in drought intensity or frequency, will affect the growth and productivity of forest ecosystems more than would a 30 percent reduction in mean annual precipitation.

- **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).

- **New Environmental Meteorology Program Initiated** - Capitalizing on the experience and data obtained in prior meteorological studies, the Atmospheric Sciences Program established a new Environmental Meteorology Program, initiating research in vertical transport and mixing and the coupling of these effects to atmospheric chemistry processes involving ozone and small particulate matter. Such research continues to support both the national and international aims of the NARSTO program.

- **Subsurface Science Program Completed** - Phaseout of the Subsurface Science Program activities will be completed in 1999, including the transition of basic research performed under BER sponsorship to the NABIR program and to applied activities supported by the Office of Environmental Management at the Test Area North, Idaho National Engineering and Environmental Laboratory. It was possible to capitalize on these earlier Subsurface Science Program field research activities to provide chemical and microbiological samples for fundamental research in bioremediation to investigators supported under the BER NABIR program.

- **Research on Long-Term Survival of Bacteria Completed** - In partnership with the Seboyetta Spanish Land Grant in rural New Mexico, research on environmental factors that control the long term survival of bacteria that are hundreds of meters deep was completed. The fact that surviving bacteria are also the most starvation-resistant bacteria has important implications for maintaining *in situ* microbial populations for bioremediation at Departmental sites. In completing the research, DOE, Land Grant authorities and residents have jointly reclaimed the drilling site, ensuring full compliance with State and Federal laws.

- **Carbon Sequestration Research Begins Under CCTI** - The carbon sequestration research program will focus on understanding the natural terrestrial sequestration cycle and the natural oceanic sequestration cycle as part of the first awards under the Climate Change Technology Initiative. The ultimate goal is to enhance the natural carbon cycle in both the terrestrial and the oceanic systems. Carbon sequestration is a key element of a more comprehensive carbon management program. Planning for joint CCTI-related activities with the Office of Fossil Energy was initiated.

Environmental Remediation

- **EMSL Attracts Wide Range of Users** - The William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) will have completed its second full year of operation as a research laboratory and user facility. In its first three months of operation, the EMSL attracted over 300 users from PNNL, other government laboratories, private industry, and academia, with over half the users coming from academia.

- **First NABIR Field Research Site** - Located at a Departmental site, the first Field Research Center for the Natural and Accelerated Bioremediation Research (NABIR) program will have been selected and field site characterization will have commenced in 1999. In addition to funding the second round of three year awards under the NABIR program, funded investigators are developing research teams that build on the strengths of the individual projects and that begin the process of integrating individual research efforts across the program elements.

Medical Applications and Measurement Science

- **New Tool for Treatment of Stroke** - A Technology Transfer Success: A multi-disciplinary team of scientists and engineers from Lawrence Livermore National Laboratory were honored after receiving the 1998 Federal Laboratory Consortium (FLC) Award for their efforts to develop a new laser technique for the treatment of stroke. The project is an excellent example of how the technology developed for national security missions can be applied successfully in the field of medical devices. The corporate partner involved in this project was EndoVasix, Inc. in Belmont, CA.

- **This is Your Brain on...** - Greater understanding of brain function is being achieved through the application of modern nuclear medicine imaging techniques such as positron emission tomography. Recent work has shown damage to brain function in persons addicted to drugs such as cocaine, this damage reinforces the craving for these drugs.

Scientific Facilities Utilization

The Biological and Environmental Research request includes $40,390,000 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 environmental remediation. This funding will provide for the operation of the facilities, assuring access for scientists in universities, federal laboratories, 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.

Climate Change Technology Initiative

Overview

The FY 2000 budget contains two carbon related programs, each of which cut across several agencies. The first is the Climate Change Technology Initiative (CCTI). That part of the CCTI that is within the Office of Science is a joint activity between the Biological and Environmental Research (BER) and Basic Energy Sciences (BES) programs. The second program is the U.S. Global Change Research Program (US/GCRP) that spans eleven agencies and is coordinated through the National Science and Technology Council's Committee on Environment and Natural Resources. Within DOE, the BER program plays the lead role in US/GCRP activities. Although the two programs, CCTI and US/GCRP, are synergistic, they are quite different. US/GCRP research focuses on developing the fundamental understanding of the comprehensive climate system and the global and regional adaptations to it. CCTI focuses on the underpinning fundamental science that will enable mitigation of climate change while maintaining a robust National economy. All research in the CCTI will be peer-reviewed fundamental scientific research; no funds will be devoted to policy studies.

Eighty-five percent of our Nation's energy results from the burning of fossil fuels, a process that adds carbon to the atmosphere — principally in the form of carbon dioxide -- from the sequestered fossil reservoir. Because of the potential environmental impacts of increases in atmospheric carbon dioxide, carbon management has become an international concern and has become the focus of CCTI. A comprehensive carbon management research and development program that meets the needs of the CCTI addresses the diverse aspects of this problem. The Office of Science is well positioned to make significant contributions to the many solutions needed for this problem, as it is set to build on the fundamental discoveries of its core programs and extend them to the new discoveries needed to make carbon management practical and efficient. The Office of Science core programs include research on both carbon and non-carbon energy sources and on both carbon sequestration and carbon recycling. These core activities can now be exploited in the generation of the science that will underpin the technologies of the future. The theme of efficiency in energy production and use must span the entire range of research activities. Research on carbon energy sources, and their impacts, is a focal point of interagency activity through the US/GCRP. Research on non-carbon energy sources is also a focal point of intra-agency activities and is led by the DOE Office of Energy Efficiency and Renewable Energy. The DOE Office of Science, through activities in both the BES program and the BER program, supports research that underpins both efforts.

A research program in carbon management would include research directed at the following themes:

(1) science for efficient technologies,

(2) fundamental science underpinning advances in all low/no carbon energy sources, and

(3) sequestration science.

The Office of Science has long standing programs in fundamental research that already impact these three categories. In FY 2000, resources of $12,656,000 are being requested by BER specifically for the CCTI. The research will be a natural extension of the complementary, ongoing work in several programs in the Office of Science. It will build on the foundation of excellent and relevant research already underway and focus on those areas that build on strengths of the current Office of Science programs and promise maximum impact in the area of carbon management. Within the BER program, the Life Sciences subprogram activities in genomics underpin studies on microorganisms that may form the core of new fuel sources. Core activities within the Environmental Processes subprogram, particularly in terrestrial carbon cycle and in ocean sciences research, open up the possibility of exploiting Nature's own carbon sequestration processes to enhance sequestration.

Immediate Impacts of Expanded Effort in the Science for Climate Change Technology

Additional Office of Science efforts will not only address an immediate societal problem, but will also have a major effect on many scientific disciplines by advancing the state of knowledge and by training students in areas of research that are important to carbon management. For example, biochemistry, molecular and cellular biology, structural biology, and genome science will be impacted, because the production of fuels and chemicals by plants and microorganisms and the interconversion of greenhouse gases requires a better understanding of metabolism, of the structure and function of sub-cellular components, and of enzymes. Similarly, the state-of-the-art in biochemistry, molecular biology, and ecology will be impacted. All of these biological processes are important in understanding the role of marine microorganisms in sequestering carbon. Improvements in combustion to reduce carbon emissions require a fundamental understanding in chemical dynamics and theoretical chemistry and physics. Conversion of sunlight to energy requires an understanding in many areas of science, including photochemistry, photosynthesis, metabolism, and solid state physics. The search for increased efficiency in energy production and use requires fundamental knowledge in ceramics, metals, polymers, solid state chemistry, and condensed matter physics for materials that can withstand higher temperatures, have lower coefficients of friction, and are stronger and lighter. Enhanced recovery of fuel resources and of disposal of carbon dioxide requires a fundamental understanding of geometric, structural, and hydrologic properties of reservoirs and of multiphase, nonlinear transport of fluids in porous and fractured structures. Crosscutting programs in nano- and meso-phase materials involve research at the forefront of materials science, chemistry, engineering, surface science, and semiconductor physics.

The new research efforts supporting advances in low/no carbon energy technologies as well as existing activities, will be closely coordinated with DOE's technology programs and will provide the knowledge base for the development of advanced technologies to reduce carbon dioxide emissions. Many of the activities will impact the Office of Energy Efficiency and Renewable Energy (EE) by providing options for increasing efficiency in automobiles by reducing weight; for increasing efficiency in the use of electricity by increasing the efficiency of electric motors and generators with better magnets; for increasing efficiency in the transmission of electricity by using superconductors; and for reducing energy consumption in manufacturing with improved sensors, controls, and processes. Much of this research program will provide the knowledge base needed to increase the use of renewable resources with research aimed at understanding the metabolism of carbon dioxide and the metabolic pathways to the production of methane and other biofuels. Other aspects of the research program impact the Office of Fossil Energy (FE) by providing a foundation for effective and safe underground sequestration, new materials, a better understanding of combustion, and improved catalysts.

Funding will be provided for areas of research in carbon cycle management including appropriate areas that will be jointly identified and implemented by the BER and BES programs. Solicitations will be issued for individual research projects. Additionally, proposal notifications may be developed jointly with the DOE energy technology programs with the intention of establishing multi-disciplinary centers at universities and national laboratories that will use the full capabilities of the institutions for a research program in carbon cycle management encompassing, for example, topics in the following areas: integration and assessment; separations; efficiency; clean fuels; bioenergy; storage and conversion; sequestration; enhanced natural terrestrial cycles; and enhanced use of major scientific user facilities to support carbon management research.

Interagency Environment

The SC program in fundamental science supporting energy technologies will be closely coordinated with, and synergistic to, the activities in its sister agencies (e.g., NASA, NSF, NOAA, USDA, DOI, and EPA) within the US/GCRP. Through its leadership role in decade to century climate prediction, BER has developed the research capability for comprehensive and large scale modeling of carbon dioxide impacts on climate, ecology, and ocean sciences, and this expertise is augmented by complementary activities in the other agencies. Similarly, the network of carbon flux measurements and ecological experiments that BER has developed serve as a backdrop to those of many other agencies, and the state-of-the-art can thus be pushed ahead more rapidly by capitalizing on the more rapidly growing base of knowledge. BER also has a leadership role within the US/GCRP on consequence evaluation of increased greenhouse gases in global climate change, including integrated assessments that address both scientific and societal (including economic) impacts of carbon management. Finally, through its pre-eminent role in the Human Genome Program and its development of the complementary Microbial Genome Program, the BER program is ideally placed to support research that will focus on the application of genetic information of microorganisms to increase metabolic efficiency related to carbon dioxide and methane production or consumption.

BER Activities

Climate Change Technology Initiative

	(dollars in thousands)	
	FY 1999	FY 2000
Life Sciences	2,434	5,841
Environmental Processes	2,921	6,815
Total	5,355	12,656

The BER program has the opportunity to take advantage of the unique research capabilities within the Environmental Processes subprogram and to determine which natural systems of forest, other plant, and marine microorganisms can be induced to increase their natural carbon sequestration capabilities. This will help to position the Department and the Nation to build new energy efficient technologies that capitalize on Nature's own processes. Additionally, through its pre-eminent role in the Human Genome Program and its development of the complementary Microbial Genome Program within the Life Sciences subprogram, the BER program is ideally placed to support research that will focus on the production of genetic information on methane-producing and hydrogen-producing microorganisms that can be exploited in the development of useful and efficient non-fossil fuel sources. Where appropriate, these efforts will be coordinated with activities within the US/GCRP. When combined with complementary activities within the BES program, this initiative will lead to the comprehensive carbon management research program described, above.

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 $101,000 and $90,000 for estimated contractor security clearances in FY 1999 and FY 2000, respectively, within this decision unit.

Scientific Simulation Initiative

This budget also includes the BER program's contribution to DOE's Scientific Simulation Initiative (SSI), an integrated effort bringing together computational and communication resources, focused research in scientific disciplines, and research in computer science and other enabling technologies to solve the complex problems that characterize DOE's scientific research needs. The SSI couples research in advanced scientific applications in the programs of the Office of Science with research in computer science and enabling technologies and advanced computing and communications facilities. It is a joint program between the Computational and Technology Research (CTR) program and the other programs in SC. The overview of the integrated program is given in the overview of the CTR budget; however, the specific contributions of the BER program are described below.

BER, which has been for many years the primary supporter of research in global systems in the DOE, will manage the global systems applications research effort. These efforts are the result of a successful interagency program to study global systems as a part of the U.S. Global Change Research Program (USGCRP), in which the Department plays a major role. These efforts will also contribute to the broader Presidential initiative in information technology. The goal of this effort is to dramatically advance the development, testing and use of fully coupled global system models with sufficient resolution to encompass the complete range of interactions from global to regional spatial scales over time periods of tens to hundreds of years. Currently, too coarse spatial resolution, inadequate representation of key processes, such as cloud effects, and an inadequate number of short-duration model runs limit simulations and predictions of the global system. The computational and informational technology developed in the global systems research effort will be used to create a bridge that enables fully collaborative research between multi-institutional teams of computational scientists, global modelers and experts in the acquisition and interpretation of observational measurements. High fidelity component models, such as general circulation simulation codes of the atmosphere and ocean will be developed and tested first, then coupled for full system simulation. The data from these simulations as well as the individual component models themselves will be employed for more disciplinary-focused research related to environmental variability and change.

In addition, the simulation products of these models will provide a valuable and unique database for the study and understanding of long-term environmental variability and change. In order to make the best possible use of this data, the global systems component will develop and employ advanced collaborative and data management technology to enable the broad and diverse base of researchers and users from the many areas of environmental and earth science to advance the knowledge in their fields with the unprecedented volume and quality of the new information about the workings of the global environment.

To accomplish its goals the Global Systems applications research effort must: (1) accelerate progress in coupled general circulation model development and application; (2) reduce substantially the uncertainties in decade-to-century model-based projections of global environmental change; and (3) increase the availability and usability of global change projections to the broader environmental research and environmental assessment communities.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Biological and Environmental Research					
Life Sciences	163,792	179,492	-3,177	176,315	163,664
Environmental Processes	105,780	120,262	-3,397	116,865	133,838
Environmental Remediation	64,497	67,435	-93	67,342	65,757
Medical Applications and Measurement Science	61,607	76,411	-245	76,166	47,911
Subtotal, Biological and Environmental	395,676	443,600	-6,912	436,688	411,170
Construction	0	0	0	0	0
Subtotal, Biological and Environmental	395,676	443,600	-6,912	436,688	411,170
Use of Prior Year Balances	-4,580 [a]	-3,798 [a]	0	-3,798 [a]	0
General Reduction for Policy Papers for CCTI	0	-5,500	5,500	0	0
General Reduction	0	-1,412	1,412	0	0
Total, Biological and Environmental Research	391,096 [b]	432,890	0	432,890	411,170

Public Law Authorization:

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

[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 $9,614,000 which was transferred to the SBIR program and $577,000 which was transferred to the STTR program.

Funding By Site

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	19,661	20,651	18,251	-2,400	-11.6%
National Renewable Energy Laboratory .	250	0	0	0	NA
Sandia National Laboratories	3,486	3,239	2,903	-336	-10.4%
Total, Albuquerque Operations Office	23,397	23,890	21,154	-2,736	-11.5%
Chicago Operations Office					
Ames Laboratory	766	631	500	-131	-20.8%
Argonne National Laboratory, East	11,278	9,181	8,487	-694	-7.6%
Brookhaven National Laboratory	26,501	22,142	19,228	-2,914	-13.2%
Total, Chicago Operations Office	38,545	31,954	28,215	-3,739	-11.7%
Idaho Operations Office					
Idaho National Environmental & Engineering Laboratory	2,158	2,034	1,736	-298	-14.7%
Oakland Operations Office					
Lawrence Berkeley National Laboratory .	34,358	31,587	29,003	-2,584	-8.2%
Lawrence Livermore National Laboratory	30,004	36,148	28,446	-7,702	-21.3%
Stanford Linear Accelerator Center (SSRL)................	3,323	2,450	2,550	+100	+4.1%
Total, Oakland Operations Office	67,685	70,185	59,999	-10,186	-14.5%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science & Education.	5,575	2,673	4,046	+1,373	+51.4%
Oak Ridge National Laboratory	25,422	21,617	19,153	-2,464	-11.4%
Total, Oak Ridge Operations Office	30,997	24,290	23,199	-1,091	-4.5%
Richland Operations Office					
Pacific Northwest National Laboratory ..	77,466	73,913	70,434	-3,479	-4.7%
All Other Sites [a]	155,428	210,422	206,433	-3,989	-1.9%
Subtotal, Biological and Environmental Research	395,676	436,688	411,170	-25,518	-5.8%
Use of Prior Year Balances	-4,580	-3,798 [b]	0	+3,798	+100.0%
Total, Biological and Environmental Research	391,096 [c]	432,890	411,170	-21,720	-5.0%

[a] Funding provided to laboratories, universities, industry, other Federal agencies and other miscellaneous contractors.

[b] 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.

[c] Excludes $9,614,000 which was transferred to the SBIR program and $577,000 which was transferred to the STTR 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 the Structural Biology Center, 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.

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 and High Flux Beam Reactor 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. Technology development research is conducted to improve current methods for high throughput DNA sequencing. Research is also conducted on the molecular mechanisms of cell responses to low doses of radiation and chemicals.

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 and funds the operation of the Brookhaven Imaging Center as a user facility for research in many branches of medicine.

Global change activities at BNL include the operation of the ARM External Data Center, a 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 chemicals 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 radiopharmaceuticals 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.

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 and chemicals, 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.

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 including minority faculty and student research fellowships, Hollaendar postdoctoral fellowships, and humanitarian research awards to scientists in the Former Soviet Union. 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 is the home to 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 is also home to the Carbon Dioxide Information and Analysis Center, an international resource for providing quality assured environmental data. 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 and chemicals.

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.

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.

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. It is the home of the Stanford Synchroton 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 25 experimental stations and is used each year by over 700 researchers from industry, government laboratories and universities. Through 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 70 colleges/universities located in 35 states. This line also includes funding of 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 and chemicals.

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. Through the National Institute for Global Environmental Change, academic scientists play essential roles in the establishment and maintenance of, and research at, the AmeriFlux sites.

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 radiopharmaceuticals, 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. Five centers of excellence for application of lasers in medicine are funded at medical schools by this program. 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:

- Integrates information and technologies from genome, structural biology, and molecular biology research with human health research to understand the complex relationships between genes, the proteins they encode, and the biological functions of these proteins in the context of the whole organism.
- Develops new biotechnologies, including those derived from microbial genome research, for bioremediation applications, and for the mitigation of potential health effects resulting from energy development, energy use, and waste cleanup.
- Supports DOE research at national user facilities for scientists to determine the molecular structure of enzymes, antibodies, and other important biological molecules. Computational structural biology research combines computer science, structural biology, and genome research to predict the functions of biological molecules. This information will enable the design or more efficient use of biological molecules for drugs, environmental cleanup, or energy-production and use.
- Develops and applies new technologies and resources to map and determine the sequence of the subunits of DNA found in a typical human cell, for analyzing and interpreting DNA sequence data, and for studying the ethical, legal, and social implications (ELSI) of information and data resulting from the genome program, especially issues of privacy, intellectual property, and education. Program 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.
- Develops new molecular-based tools for health surveillance, biological dosimetry, and individual susceptibility determination to understand and characterize the risks to human health from exposures to low levels of radiation and chemicals both at home and at work. An emphasis is placed on research that utilizes the unique resources and tools developed in the Department's human genome, structural biology, and cellular and molecular biology programs.

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 give off hydrogen.

Performance Measures

- Determine the molecular structures of proteins with more than 60 percent of the new structures that are published in the peer reviewed literature resulting from data generated at synchrotron user stations by BER structural biology program.
- Complete the sequencing of 50 million finished and 70 million draft subunits of human DNA to submit to publicly accessible databases in FY 2000.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Structural Biology	29,962	27,086	28,145	+1,059	+3.9%
Molecular and Cellular Biology	30,402	36,140	23,380	-12,760	-35.3%
Human Genome	85,226	88,786	90,270	+1,484	+1.7%
Health Effects	18,202	19,975	17,854	-2,121	-10.6%
SBIR/STTR	0	4,328	4,015	-313	-7.2%
Total, Life Sciences	163,792	176,315	163,664	-12,651	-7.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Structural Biology			
■ Infrastructure support and development for the Nation's structural biologists. Development and operation of experimental stations at DOE national user facilities such as the synchrotrons and neutron beam sources. Completion of development and initial operation of the protein crystallography station at the Los Alamos Neutron Science Center. Support for the major three-dimensional structural database for proteins.	17,003	16,000	16,000
■ Basic research in structural biology including instrumentation research and research that cuts across basic biology, molecular biology, and computational biology. Completion of initial studies of inverse protein folding to understand the rules proteins follow to acquire the three dimensional structure that gives them their biological function. First prototypes of pixel array detectors for x-rays will be ready for field testing that will greatly increase the sensitivity and speed data collection needed for determining the structure and, ultimately, the function of proteins. Implementation of proteome research program to understand the structure, function, and interactions of all proteins encoded by an organism's genome.	12,959	11,086	12,145
Total, Structural Biology	29,962	27,086	28,145

Molecular and Cellular Biology

■ The field of microbial genomics is one of the most exciting and high profile fields in biology today. Initiated by DOE in 1994, microbial genomics and microbial genomic sequencing were identified by *Science* magazine as one of the top 10 fields of discovery in both 1997 and 1998. The BER Microbial Genome Program has supported the complete genomic sequencing of 6 of the 18 bacteria whose DNA has

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
been sequenced and published. At least 12 more are in progress. 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 because of potential impacts across several DOE missions. These include the Climate Change Technology Initiative (sequencing methane or hydrogen producing microbes or microbes involved in carbon dioxide sequestration), environmental cleanup (microbes for bioremediation), alternative fuel sources (methane production or energy from biomass), industrial processes (industrial useful enzymes), and biological nonproliferation (understanding and detecting biowarfare agents). The microbial genome program continues to capitalize on DNA sequencing technology from the human genome program to determine the complete DNA sequence of microbes with potential environmental, energy, or commercial applications. While the program continues its emphasis on DNA sequencing it has expanded to include research in three additional areas: (1) microbial diversity, to identify a broader array of potentially useful microbes; (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; and (3) novel strategies and tools for characterizing, manipulating, and modeling entire reaction pathways or regulatory networks of microbes or groups of microbes to maximize the usefulness of these newly characterized microbes.	5,200	7,000	8,860

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
■ The Climate Change Technology Initiative (CCTI) continues to determine the DNA sequence of microbes that produce methane or hydrogen from carbonaeous sources or that could be used to sequester carbon dioxide. New research is being initiated to characterize key reaction pathways or regulatory networks in these microbes following the determination of their DNA sequence. These new studies focus on the development of practical uses for microbes within the CCTI.	0	2,434	5,841
■ Funding was provided for the Northeast Regional Cancer Institute in Scranton, Pennsylvania per Congressional direction for FY 1998 and for the Institute for Molecular Biology and Medicine, University of Scranton, Scranton, Pennsylvania, per Congressional direction for FY 1999. . . .	9,735	10,189	0
■ Molecular biology research, as a general research area, comes to an end with the exception of continued funding for the Human Science Frontiers Program, an international program of collaborative research to understand brain function and biological function at the molecular level supported by U.S. government through the DOE, the National Institutes of Health, the National Science Foundation, and the National Aeronautics and Space Administration.	6,735	4,684	1,000
■ The low dose exposure program uses molecular level knowledge gained from the Department's human genome and structural biology research to ascertain the effects on humans, ranging from cells to the whole organism, that arise from low-dose-rate exposures to energy and defense-related insults such as radiation and chemicals. 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.	3,000	8,000	7,679
■ Cellular biology research, as a general research area, comes to an end and is replaced by the low dose exposure program.	5,732	3,833	0
Total, Molecular and Cellular Biology	30,402	36,140	23,380

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
Human Genome			
■ The Joint Genome Institute (JGI) and its Production Sequencing Facility (PSF) are primarily focused on high throughput sequencing of human DNA. The JGI is a virtual institute formed from the combined strengths and expertise of the DOE Human Genome Centers at the Los Alamos, Lawrence Livermore, and Lawrence Berkeley National Laboratories. FY 2000 is the third year of a major 3-5 year scale-up in DNA sequencing capacity for the PSF. In FY 2000 the PSF will complete the sequencing and submission to public databases of 50 million finished and 70 million high quality draft base pairs of human DNA.	46,300	50,000	53,894
■ Improvements in high throughput human DNA sequencing technology and sequence data management are needed to complete the first human genome by 2003 and to most efficiently and cost effectively use that new sequence information for future medical diagnoses and new scientific discovery. Research is conducted to continue the incremental improvements in current DNA sequencing technology by increasing throughput, increasing accuracy, and decreasing cost. New sequencing technologies, that have been investigated on a pilot scale, are tested and “hardened” in a DNA sequencing production environment. Research is conducted on the next generation of sequencing technology that will be needed to take advantage of the DNA sequence to be determined after 2003. Research on automated and robust approaches to analyze and manage the large amounts of DNA sequence being determined continues. These approaches will replace the hands-on, gene-by-gene analyses traditionally used by scientists to make their initial analyses of newly discovered or identified genes. A table follows displaying both DOE and NIH genome funding.	36,411	36,226	33,816

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
■ The Ethical Legal and Societal Issues (ELSI) program increases 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.	2,515	2,560	2,560
Total, Human Genome	85,226	88,786	90,270

U.S. Human Genome Project Funding

(dollars in millions)

	Prior Years	FY 1998	FY 1999	FY 2000
DOE Total Funding (includes construction)	457.3	85.2	88.8	90.3
NIH Funding	1,234.4	218.0	240.1	TBD
Total U.S. Funding	1,691.7	303.2	328.9	TBD

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
Health Effects			
■ The low dose exposure program, also funded under Cellular Biology, uses molecular level knowledge gained from the Department's human genome and structural biology research to ascertain the effects on humans, ranging from cells to the whole organism, that arise from low-dose-rate exposures to energy and defense-related insults such as radiation and chemicals. 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	0	2,321

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
■ 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. Research is conducted at a genomic or near-genomic scale, i.e., not, for example, at the level of individual genes, and focuses on understanding of human genome organization, regulation, and function. Funding to be provided to ORNL to continue conceptual design activities for the Center for Functional Genomics.	0	9,000	11,027
■ Technology development research results in new approaches, tools, or technologies for determining the structures of many more proteins than is currently possible and includes more efficient strategies for protein expression and more efficient, high-throughput methods of protein sample preparation for protein crystallization. Research to develop and use protein microarray systems for functional screening of large numbers of proteins is also conducted.	0	3,000	4,506
■ Biological research, as a general research area, comes to an end.	18,202	7,975	0
Total, Health Effects	18,202	19,975	17,854
SBIR/STTR			
■ In FY 1998, $3,872,000 and $233,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts shown are the estimated requirement for the continuation of these programs.	0	4,328	4,015
Total, Life Sciences	163,792	176,315	163,664

Explanation of Funding Changes From FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Structural Biology	
■ Structural biology research increases as proteome research program is implemented	+1,059
Molecular and Cellular Biology	
■ Increase in Microbial Genome for new research on microbial diversity, gene networks, and strategies for DNA sequencing that capitalize on known DNA sequence.	+1,860
■ Increase in Climate Change Technology Initiative (CCTI).	+3,407
■ Decrease in Molecular Biology due to completion of traditional Molecular Biology research and development and expansion of new research programs and completion of Congressionally directed project.	-13,873
■ Continue low dose research at FY 1999 level	-321
■ Decrease in Cellular biology research due to completion of traditional Cellular Biology research and development and expansion of a new low dose research program in Cellular Biology	-3,833
Total, Molecular and Cellular Biology	-12,760
Human Genome	
■ Increase for Human Genome research due to increase in sequencing of human DNA to meet national program goals	+1,484
Health Effects	
■ Increase in low dose research due to continued expansion of new crosscutting program to understand the health impacts of low dose exposures to radiation and chemicals	+2,321
■ Increase in model organisms research due to increased emphasis on research to understand human genome organization, regulation, and function	+2,027

	FY 2000 vs. FY 1999 ($000)
■ Increase in technology development research due to increased emphasis on developing new methods for determining the structure and function of large numbers of proteins	+1,506
■ Decrease in Biological Research due to completion of traditional Biological Research program and development and expansion of new research programs .	-7,975
Total, Health Effects	-2,121
SBIR/STTR	
■ Decrease in SBIR/STTR due to reduction in research funding.	-313
Total Funding Change, Life Sciences	-12,651

Environmental Processes

Mission Supporting Goals and Objectives

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 Carbon Cycle program is designed to study the natural carbon cycle and to assess the potential impacts of climate change on terrestrial systems. There are four contributing areas to this research program: Climate and Hydrology, Atmospheric Chemistry and Carbon Cycle, Ecological Processes, and Human Interactions. The National Institute for Global and Environmental Change (NIGEC) is included within these four areas. 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 Energy Research 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 and human activities play on the state and quality of the global climate. Complementing the activities in support of the U.S. Global Change Research Program, science for the Climate Change Technology Initiative seeks the understanding necessary to exploit the biosphere’s natural processes for use in sequestration of atmospheric carbon dioxide including the roles of marine microorganisms in ocean carbon sequestration and the mechanisms by which forest ecosystems sequester carbon.

Scientific Simulation Initiative

Building on the long-standing BER expertise in climate modeling, the Scientific Simulation Initiative will create a bridge between computational scientists, global modelers, and experts in the acquisition and interpretation of observational measurements to develop, test, and use highly advance fully coupled global system models. The focus will be on models that are of much higher spacial resolution than currently available, and model runs will simulate climate over time periods of tens to hundreds of years, at fidelities that cannot be achieved with current hardware or software. In doing so, the SSI will bring together expertise from academia and the federal laboratories, and couple activities in a synergistic way to bring global system modeling to a broader spectrum of environmental research than is currently possible.

Performance Measures

- Proceed on the development of the next generation coupled ocean-atmosphere climate model, leading to better information for assessing climate change and variability at regional, rather than global scales. This next generation model will change grid size from the current 300-500 kilometers on a side to less than 200 kilometers on a side.
- Coordinate with other federal agencies, Canada, and Brazil to maximize national and international capabilities to enhance understanding of the current global carbon dioxide distribution and the role of the terrestrial biosphere in that distribution.
- Develop collaborative partnerships between strong marine sciences research institutions and those with developing capabilities to advance innovative techniques in modern molecular biology to understand the coupling between carbon and nitrogen cycles in coastal waters and sediments.
- In cooperation with NASA, NSF, USDA/Forest Service, and the Smithsonian Institution, provide quantitative data on the annual exchange of carbon dioxide between the atmosphere and terrestrial ecosystem from 25 AmeriFlux sites representing major types of ecosystem and land uses in North Central America. Provide data on both the effects of environmental factors, such as climate variation, on the net sequestration or release of carbon dioxide and the role of biophysical processes controlling the net exchange.
- Commence full operation at three Atmospheric Radiation Measurement (ARM) sites, providing unique climatological data necessary to improve climate prediction for use in energy policy development. Continue ARM accomplishments by conducting five intensive operations periods at the ARM Southern Great Plains site. Data will be obtained from the second station on the North Slop of Alaska. The third station in the Tropical Western Pacific, on Christmas Island, will become operational.
- Continue The Global Change Research Education Program which will continue to support graduate and undergraduate students conducting DOE-related global change research. It will continue to participate in the multi-agency “Significant Opportunities in Atmospheric Research and Science” Program (SOARS).

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Climate and Hydrology	63,150	64,093	74,383	+10,290	+16.1%
Atmospheric Chemistry and Carbon Cycle . .	20,675	29,972	32,924	+2,952	+9.8%
Ecological Processes	13,084	12,348	12,010	-338	-2.7%
Human Interaction	8,871	7,483	11,105	+3,622	+48.4%
SBIR/STTR	0	2,969	3,416	+447	+15.1%
Total, Environmental Processes	105,780	116,865	133,838	+16,973	+14.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
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 on the supercomputers at the LANL Advanced Computing Laboratory.	20,469	21,336	20,274
■ **Scientific Simulation Initiative (SSI):** Regional Variability Associated with Global Changes: There is a need to analyze and downscale global climate model simulations to smaller scales for regional studies of environmental changes. Methodologies to do so will be developed and implemented using a hierarch of applied and engineering models. Technologies will be developed and employed 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 and their impacts. Two centers connected to the core SSP infrastructure will be established to access the primary data archive and computational facilities.	0	0	3,902

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Scientific Simulation Initiative (SSI):** Coupled Model Development, Testing and Application: With its partners in the multi-agency U.S. Global Change Research Program, DOE will establish two multi-institutional model development teams for research on fully coupled comprehensive 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.	0	0	2,930
■ **Scientific Simulation Initiative (SSI):** Component Model Research and Development: Initiate research to pursue improvements in predictability, numerical methods, and parameterizations needed for improving the fidelity and computational performance of the component models, such as atmospheric and ocean general circulation models, that integrate to form comprehensive, coupled climate models.	0	0	2,930
■ **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 on Christmas Island. Redeploy ARM instruments used in the Surface Heat Budget of the Arctic Ocean (SHEBA) as the second North Slope of Alaska station. Provide data to scientific community through the ARM Archive.	28,017	28,224	27,371

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Atmospheric Radiation Measurement (ARM):** ARM research will support about 50 principal investigators working on cloud physics and on solar radiation interactions with water vapor and aerosols. Conduct the ARM-led, multi-agency and Japanese experimental campaign on Nauru (Tropical Western Pacific) to study the effects of islands in measuring solar radiation and cloud interactions with the oceans. Enhance interactions with prominent climate modeling centers, including those supported by the NSF and by NOAA. Additional field studies will focus on connection of ARM data with carbon cycle research	11,659	11,659	14,093
■ **Atmospheric Radiation Measurement (ARM)/Unmanned Aerial Vehicles (UAV):** The joint ARM-UAV and NASA field study of tropical cirrus clouds will provide new information on key cloud formations that moderate the radiation budget of the Earth.	3,005	2,874	2,883
Total, Climate and Hydrology	63,150	64,093	74,383

Atmospheric Chemistry and Carbon Cycle

■ Atmospheric Science programs provide data that address the new air quality standards on tropospheric ozone and particulate matter. Conduct laboratory and field studies of the chemistry and reactivity of atmospheric species and transport. Support tropospheric ozone and aerosols studies, in conjunction with the North American Research Strategy for Tropospheric Ozone (NARSTO). Support air quality modeling and initiate pollution transport studies (and related aspects of weather forecasting). Complete the data analysis for the prototype megacity air quality study in Mexico City, Mexico. Partial support for the National Institute for Global Environmental Change (NIGEC) is included in this budget activity.	12,856	12,967	11,278

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ Field studies of major ecosystem types and land uses provide data to better understand the effects of environmental factors such as climate variation on the net exchange of carbon and the role of biophysical processes controlling this exchange. Operate the AmeriFlux network of twenty-five instrumented research towers for measurements of long-term carbon dioxide and water vapor fluxes and energy exchange from a large variety of ecosystems. Using tools of microbiology explore linkages between carbon and nitrogen cycles in marine microbes by partnering institutions with traditional research in oceans and those with emerging capabilities.	7,819	13,113	14,831
■ Funding was provided for the Marine Mammal Research and Education Center at the National Energy Laboratory at Keahole Point, Hawaii, per Congressional direction in FY 1999.	0	971	0
■ Under the Climate Change Technology Initiative, improve understanding of biochemical mechanisms of natural carbon sequestration in both terrestrial and ocean systems in order to, ultimately, enhance or augment these natural processes. Conduct studies on the cellular processes that lead to sequestration in forest ecosystems and the identification of the pathways by which marine microorganisms enhance carbon flow from the atmosphere to ocean surface and, ultimately, to the deep ocean.	0	2,921	6,815
Total, Atmospheric Chemistry and Carbon Cycle	20,675	29,972	32,924

Ecological Processes

- Improve understanding and modeling of the effects of elevated carbon dioxide on whole ecosystem structure and function that effect the nation's resources. Investigate the relationship between precipitation and the regeneration and species composition of deciduous forests in Tennessee's Walker Branch Watershed. Analyze the effects of precipitation changes on nutrient cycling, carbon

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
sequestration, forest growth, and decomposition in a southeastern deciduous forest. Free Air Carbon Dioxide Enrichment (FACE) experiments at Duke Forest; the Nevada desert; Oak Ridge, TN; Cedar Creek, MN; and Rhinelander, WI, will provide data on the effects of elevated carbon dioxide and other environmental changes on forest, desert, and grassland ecosystems. Partial support for the NIGEC is included in this budget activity.	13,084	12,348	12,010

Human Interactions

- The Integrated Assessment program investigates the diffusion of technology innovation into societal use and develops expanded economic models to include consideration of five additional greenhouse gases (nitrous oxide, methane, CFC 11, HCFC 22, and CF4) other than carbon dioxide. 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) NARSTO. The educational activities support DOE mission-related research into global environmental change by students at the undergraduate and graduate levels. Included in these activities are the Summer Undergraduate Research Experience, Graduate Research agency "Significant Opportunities in Atmospheric Research and Science" Program. Partial support for the National Institute for Global Environmental Change is included in this budget activity. BER will provide opportunities for pre-college teachers that will participate directly in cutting-edge research at DOE science laboratories and will renew their understanding of scientific investigation. Where teachers do not possess sufficient background to participate directly in research, DOE will provide mediated research experiences where teachers can work with teams of scientists and science educators to understand the nature of DOE's scientific research. The goal is to provide educators with the tools to sharpen their science and math foundations and apply these tools to their classroom practice. Funds

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
will be provided to pay for teacher's stipends, travel, housing, and subsidize laboratory scientists' time for this activity ($1,947,000).	8,871	7,483	11,105
SBIR/STTR			
■ In FY 1998, $2,625,000 and $154,000 were transferred to the SBIR and STTR programs, respectively. In FY 1999 and FY 2000 amounts shown are the estimated requirement for the continuation of these programs.	0	2,969	3,416
Total, Environmental Processes	105,780	116,865	133,838

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Climate and Hydrology	
■ Represents transition of some high end computing developments to activities under the SSI.	-1,062
■ SSI. Initiate activities to develop methodologies and research collaborations to increase fidelity and resolution of global systems simulations..	+9,762
■ Reflects that the ARM research sites are at increased stages of development . .	-853
■ Increase to provide for data collection to enhance scientific understanding of coupling between clouds, radiation, and atmospheric part of carbon cycle	+2,434
■ ARM-UAV to continue at FY 1999 level of effort	+9
Total, Climate and Hydrology	+10,290
Atmospheric and Carbon Cycle	
■ Represents completion of prototype megacity air quality study in Mexico City, Mexico.	-1,689
■ Increase to provide for data collection to validate carbon cycle.	+1,718
■ Decrease due to completion of Congressionally directed project.	-971

	FY 2000 vs. FY 1999 ($000)
■ CCTI. Increased focus on ocean and terrestrial sequestration by natural ecosystems.	+3,894
Total, Atmospheric and Carbon Cycle	+2,952
Ecological Processes	
■ Ecological Processes continues at FY 1999 level.	-338
Human Interactions	
■ Increase will allow new activities coupling educational opportunities with research in environmental meteorology and will allow pre-college teachers to participate directly in cutting-edge research at DOE science laboratories.	+3,622
SBIR/STTR	
■ SBIR/STTR increase due to increase in research funding.	+447
Total Funding Change, Environmental Processes	+16,973

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 global warming.

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.

Performance Measures

- Continue the Natural and Accelerated Bioremediation Research (NABIR) program to support fundamental research in environmental and molecular sciences that will underpin the development of bioremediation for containing hazardous waste and cleaning DOE sites. Site characterization of the first NABIR Field Research Center will proceed, and activities necessary to enable research sample distribution to investigators will commence.
- The William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) will be identified and cited as an important resource in research publications and research proposals written by investigators in academia and at National Laboratories.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Bioremediation Research	28,781	28,895	28,039	-856	-3.0%
Clean Up Research	5,527	6,817	6,773	-44	- 0.6%
Facility Operations	30,189	30,072	29,415	-657	-2.2%
SBIR/STTR	0	1,558	1,530	-28	-1.8%
Total, Environmental Remediation	64,497	67,342	65,757	-1,585	-2.4%

Detailed Program Justification

(dollars in thousands)

	FY 1998	FY 1999	FY 2000

Bioremediation Research

- In NABIR, progress will be made in understanding both intrinsic bioremediation as well as manipulated, accelerated bioremediation using chemical/microbial amendments. Laboratory and field experiments will be in progress to understand the fundamental mechanisms underlying chemical processes, complexation/degradation, and microbial transport. Field site characterization of the first NABIR Field Research Center will proceed, in preparation for distribution of research samples to investigators. Three megabases of genomic DNA from microbes with potential utility in bioremediation will be sequenced. The interagency (DOE, National Science Foundation, Office of Naval Research,

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Environmental Protection Agency) program on environmental biotechnology will continue to be supported, completing the current awards, to advance understanding of the fundamental processes that control the bioavailability of complex chemical mixtures in field situations.	22,437	22,915	22,059
■ 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.	5,194	4,811	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.	1,150	1,169	1,169
Total, Bioremediation Research	28,781	28,895	28,039
Clean Up Research			
■ A program will be maintained to develop cost effective and efficient biotechnology and bioremediation methods and approaches for pollution prevention in key energy and pollution intensive industries. This includes additional research to characterize the geological, chemical, and physical properties that affect the rate and effectiveness of environmental remediation and waste-stream cleanup methods, including bioremediation.	5,527	6,817	6,773

(dollars in thousands)	FY 1998	FY 1999	FY 2000
Facility Operations: William R. Wiley Environmental Molecular Sciences Laboratory (EMSL)			
■ EMSL became fully operational as a national user facility focusing on collaborative research, in FY 1998. Operating funds provide essential maintenance of instruments and associated support facilities, and the technical and Environmental, Safety and Health support needed by the wide-ranging user community to apply the EMSL scientific capabilities. EMSL will support about 600 users on an annual basis, with approximately half coming from academia to use such unique instrumentation as the 512- processor IBM SP computer system, the 750-MHZ and ultra high-field nuclear magnetic resonance spectrometers, the ultra-high vacuum scanning tunneling and atomic force microscopes, and the controlled atmosphere environmental chambers. . . .	27,057	28,083	27,426
■ Capital equipment support for the EMSL enables instrument modifications needed by collaborators and external users of the facility and helps to maintain the spectroscopic and computer equipment at state-of-the-art.	3,132	1,989	1,989
Total, Facility Operations	30,189	30,072	29,415
SBIR/STTR			
■ In FY 1998, $1,461,000 and $88,000 were transferred to the SBIR and STTR programs, respectively. In FY 1999 and FY 2000 amounts shown are the estimated requirement for the continuation of these programs.	0	1,558	1,530
Total, Environmental Remediation	64,497	67,342	65,757

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Bioremediation Research	
■ Decrease in pollution prevention and sustainable development activities.	-856
Clean Up Research	
■ Decrease in pollution prevention and sustainable development activities.	-44
Facility Operations	
■ Decrease in Facility Operations will result in fewer hours of fully supported assistance for outside users working independently, rather than collaboratively, at the facility	-657
SBIR/STTR	
■ SBIR/STTR decrease due to reduction in research funding.	-28
Total Funding Change, Environmental Remediation	-1,585

Medical Applications and Measurement Science

Mission Supporting Goals and Objectives

The medical applications subprogram 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. The research in this activity is conducted in five specific areas: Radiopharmaceuticals, Instrumentation, Clinical Feasibility, Boron Neutron Capture Therapy (BNCT) and Molecular Nuclear Medicine.

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

Performance Measures

- Complete Phase I clinical trials of BNCT at reactor sources of neutrons for at least 100 patients.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Medical Applications	56,841	69,084	40,817	-28,267	-40.9%
Measurement Science	4,766	5,087	5,849	+762	+15.0%
SBIR/STTR	0	1,995	1,245	-750	-37.6%
Total, Medical Applications and Measurement Science	61,607	76,166	47,911	-28,255	-37.1%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Medical Applications			
■ Complete Phase I human clinical trials of boron neutron capture therapy (BNCT), for at least 100 patients, at Brookhaven National Laboratory, Massachusetts Institute of Technology and the Ohio State University, including trials to assess the maximum safe dosages of boron compound and neutron radiation. 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.	11,648	11,441	10,892
■ 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, including research at the Garden State Cancer Center in the diagnosis of cancer and infectious diseases. Evaluate clinical potential of imaging of gene expression using radiotracers. Redirect program elements to emphasize development of techniques for the simultaneous use of multiple radiotracers to study physiological processes.	18,360	20,233	24,700
■ Develop new concepts in multimodal imaging systems for study of human brain function and complete evaluation of combination of nuclear medicine imaging systems with magnetic resonance imaging. Research into new applications of lasers in medicine emphasizes transfer of technology from the DOE laboratories to clinical research facilities. Capital equipment funds are provided in support of development of new instrumentation such as a PET camera for small animal imaging.	4,946	5,877	5,225
■ Complete phase-out of research into new radioisotopes for nuclear medicine applications.	36	0	0

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ Funding for the Medical University of South Carolina, Loma Linda Medical Center, the University of California-Davis, the University of Rochester Medical Center, Englewood Hospital in New Jersey, the University of Nevada, Las Vegas, and New Mexico Highlands University as included in Congressional direction for FY 1998. Funding for these projects is completed in FY 1998.	21,851	0	0
■ Funding 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, as included in Congressional direction for FY 1999. Funding for these projects is completed in FY 1999.	0	31,533	0
Total, Medical Applications	56,841	69,084	40,817
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 environmental and life sciences applications. Capital equipment funds are provided for components needed for research into new instrumentation.	4,766	5,087	5,849
SBIR/STTR			
■ In FY 1998, $1,656,000 and $102,000 were transferred to the SBIR and STTR programs, respectively. In FY 1999 and FY 2000, amounts shown are the estimated requirement for the continuation of these programs.	0	1,995	1,245
Total, Medical Applications and Measurement Science	61,607	76,166	47,911

Explanation of Funding Changes From FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Medical Applications	
■ BNCT—maintains program at FY 1999 level of effort.	-549
■ Increased funding for Radiopharmaceuticals allows for research efforts at the Garden State Cancer Center	+4,467
■ Decrease in instrumentation is attributable to complete development of imaging instrumentation	-652
■ Decrease due to completion of Congressionally directed projects.	-31,533
Total, Medical Applications.	-28,267
Measurement Science	
■ Increased funding for research in new sensor instrumentation for characterization of chemical composition of contaminated environments.	+762
SBIR/STTR	
■ SBIR/STTR decrease due to reduction in research funding.	-750
Total Funding Change, Medical Applications and Measurement Science	-28,255

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
General Plant Projects	5,194	4,811	4,811	0	0.0%
Capital Equipment	19,089	18,988	21,150	+2,162	+11.4%
Total Capital Operating Expenses	24,283	23,799	25,961	+2,162	+9.1%

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 continuously 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;
- Foster and support the discovery, dissemination, and integration of the results of fundamental, innovative research in these areas;
- Provide world-class scientific user facilities for the Nation; 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 scientific and engineering knowledge in areas important to the BES mission, i.e., in materials sciences, chemical sciences, geosciences, plant and microbial biosciences, and engineering sciences.
- *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.
- *Plan, construct, and operate premier national scientific user 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. In addition, to 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.

- *Establish and maintain stable, essential research communities, institutions, and scientific user facilities.* — Steward important research communities and institutions in order to respond quickly and appropriately to mission need and scientific opportunity. For example, BES serves as the Nation's primary or sole supporter of such important subdisciplines as heavy element chemistry, natural and artificial solar energy conversion, catalysis, organometallic chemistry, combustion related science, separations science, neutron science, radiation chemistry, and radiation effects in materials.

Performance Measures

BES is prototypical of a large, diverse, and robust basic research program that exists within a mission agency. BES measures performance in four areas that together characterize this special role. The first three areas relate to the fundamental tenets or principles of BES, which correspond directly to the goals described above. These tenets are: (1) excellence in basic research; (2) relevance to the comprehensive energy mission of the agency; and (3) stewardship of research performers, essential scientific disciplines, institutions, and scientific user facilities. Combining and sustaining these tenets are the management challenge of BES. The fourth area that BES measures performance in, therefore, is program management.

Activities in these four areas are measured in a number of ways, which separate naturally into four categories: (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 in order to better quantify performance. 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, 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, now is completed annually by all BES facilities. An integral part of the survey tool is an assessment of user satisfaction. The tool has generated considerable interest outside of BES and has been distributed to other organizations and non-BES facilities at their request. Third, BES began formal peer reviews of its major scientific user facilities. These reviews, the first of which was documented in the 1997 Basic Energy Sciences Advisory Committee (BESAC) report on synchrotron radiation light sources (“Synchrotron Radiation Sources and Science” chaired by Professor Robert Birgeneau, MIT), assess in the aggregate, the scientific output and, to the extent possible, the outcomes of facilities. The High-Flux Isotope Reactor at Oak Ridge National Laboratory was reviewed in this manner in FY 1998. The four electron beam microcharacterization centers will be reviewed in FY 1999.

In FY 2000, (1) the development and upgrade of scientific user facilities, including the construction of the Spallation Neutron Source, will be kept on schedule and within cost, not to exceed 110 percent of estimates; (2) 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; (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; (5) work performed by investigators in universities and DOE laboratories will continue to be recognized as outstanding through the receipt of major prizes and awards; (6) continue Partnerships for Academic-Industrial Research where peer reviewed grants are awarded to university researchers for fundamental, high-risk work jointly defined by the academic and industrial research partners; and (7) continue fabrication of instrumentation for the short-pulse spallation source on the Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center.

Performance measurement helps determine the distribution of activities supported within BES and the individual projects supported within each activity. The funding level for each activity is derived by weighing a number of additional factors including mission need as defined by the BES and SC mission statements; scientific opportunity as determined, in part, by proposal pressure and by scientific workshops; connections with other BES and SC supported work; connections with needs expressed by the DOE technology offices and by energy-intensive industries; program balance; and budgetary constraints.

Prizes, Awards, and Honors

Annually, principal investigators funded by BES win dozens of major prizes and awards sponsored by professional societies and by others; in addition, many are elected to fellowship in organizations such as the National Academy of Sciences, the National Academy of Engineering, and the major scientific professional societies. Paramount among the honors in FY 1998 was the Nobel Prize in Chemistry. The Nobel Prize in Chemistry for 1997 was awarded to three biochemists, Paul D. Boyer (University of California at Los Angeles), John E. Walker (Medical Research Council Laboratory of Molecular Biology of Cambridge, England) and Jens C. Skou (Aarhus University in Denmark). Drs. Boyer and Walker were cited for their elucidation of the enzymatic mechanism underlying the synthesis of adenosine triphosphate (ATP). Dr. Boyer’s work was supported in part by the BES Energy Biosciences subprogram and its predecessor organizations from 1963 until his retirement in 1993. This is the fourth Nobel Prize awarded to BES principal investigators in the past four years.

Other selected major prizes and awards for FY 1998 include:

From the American Ceramic Society — the Robert L. Coble Award; the Long-Term Service Award; the Sosman Memorial Lecture

From the American Chemical Society — the Analytical Chemistry Award in Electrochemistry; the Arthur C. Cope Scholar Award in Organic Chemistry; the Arthur W. Adamson Award for Distinguished Service in the Advancement of Surface Chemistry; the E. V. Murphree Award in Industrial and Engineering Chemistry; the Award in Chromatography; the Irving Langmuir Award in Chemical Physics; the Award in Spectrochemical Analysis; the Arthur K. Doolittle Award for Best Paper at the Polymeric Materials Science and Engineering Division meeting

From the American Institute of Aeronautics and Astronautics — the Award for Distinguished Service

From the American Institute of Chemical Engineers — the Professional Progress Award; the Research Achievement Award; the Thomas Chilton Award; the Warren K. Lewis Award

From the American Institute of Chemists — the Chemical Pioneer Award

From the American Physical Society — the David Adler Lectureship Award in the Field of Materials Physics; the Davisson-Germer Prize in Atomic or Surface Physics; the Earle K. Plyler Prize in Molecular Spectroscopy; the Frank Isakson Prize for Optical Effects in Solids; the Joseph F. Keithley Award for Advances in Measurement Science; the Julius Edgar Lilienfield Prize; the Centenial Speaker Award

From the American Society for Mass Spectroscopy — the Biemann Medal; the Distinguished Contribution Award

From the American Society of Plant Physiologists — the Stephen Hales Prize

From the American Welding Society — the Burton Medal; the Masubuchi Award; the Warren F. Savage Memorial Award

From the Electrochemical Society — the Olin Palladium Award Lecture

From the Eli Lilly Corporation — the Eli Lilly Award

From the Federal Planning Division of the American Planning Association — the Best 1998 Area Development Plan (Spallation Neutron Source, ORNL)

From the Geological Society of America — the Day Medal

From the IBM Corporation — the Supercomputer Award

From the Institute of Electrical and Electronic Engineers — the Prize Paper Award

From the Inter-American Photochemical Society — the Inter-American Society Award

From the International Association for Structural Safety and Reliability — the IASSAR Research Award

From the International Electron Paramagnetic Resonance/Electron Spin Resonance Society (IES) — the Silver Metal for Chemistry

From the International Organization on Multiphase Flow — the Multiphase Flow International Prize

From the International Society of Electrochemistry — the Prix Jacques Tacussel Award

From the Japan Society for the Promotion of Science — the International Prize for Biology

From the Japan Society of Multiphase Flow — the Lifetime Achievement Award

From the Materials Research Society — the von Hippel Award; the Graduate Student Award

From the Microbeam Analysis Society — the Heinrich Award

From the Microscopy Society of America — the Outstanding Technologist Award

From the Mineralogical Society of America — the Mineralogical Society of America Award

From the North American Catalysis Society — the Robert Burwell Lectureship Award*;* the International Catalysis Award

From *R&D Magazine* — R&D 100 Awards for TRUST- Terminal Repeller Unconstrained Subenergy Tunneling; SAMMS - Self-Assembled Monolayers or Mesoporous Supports; and MICLEAN/MICARE Solvent Cleaning Systems

From the Science Museum of Virginia and the State of Virginia General Assembly — the Virginia Outstanding Scientist

From the Semiconductor Research Corporation — the Aristotle Award

From the Serbian Chemical Society — the Centenary Medal

From the Society for Technical Communication — the Technical Communcation Award

From the Society of Applied Spectroscopy, New England Section — the Lester W. Strock Award

From the Wolf Foundation — the Wolf Foundation Prize in Chemistry

From Vice President Gore — the Hammer Award

Two principal investigators received the Presidential Young Investigator Award; five were inducted into the National Academy of Sciences; one was inducted into the National Academy of Engineering. Seven principal investigators were advanced to fellowship in the American Academy of Arts and Sciences; three in the American Association for the Advancement of Science; four in the American Ceramic Society; nine in the American Physical Society; two in the American Society for Metals; and one each into the following organizations: Geological Society of America, Institute of Electrical and Electronic Engineers, the American Welding Society, National Science Foundation/Japanese Science Technology Agency, Optical Society of America, and the Royal Society of New Zealand.

Finally, principal investigators served in numerous elected offices including: President, American Chemical Society; President, International Society of Electrochemistry; President, Mineralogical Society of America; President-elect, American Ceramic Society; President-elect, American Society of Plant Physiologists; Vice President, American Physical Society; Chair, Division of Materials Physics, American Physical Society; and First Vice Chair, American Society for Testing and Materials.

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, biosciences, and engineering sciences. The program encompasses more than 2,400 researchers in 200 institutions and 17 of the Nation's premier user facilities. Presented below are program accomplishments from FY 1998. 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 often be incorporated into other scientific desciplines and into the commercial sector, and the great potential of new knowledge for future impacts in energy production and use. Following that are discussions of scientific facilities and program initiatives.

Selected FY 1998 Scientific Highlights/Accomplishments

Materials Sciences

- *Helping to Solve the Mystery of High-Temperature Superconductivity.* Understanding high-temperature superconductivity, discovered in 1987, remains *the* outstanding problem in modern condensed matter physics. Recent neutron scattering experiments suggest that the electric current in high temperature superconductors may be like “stripes” of flowing current separated by stripes where current does not flow. These stripes can be static or dynamic (like the stripes on our flags, waving in the wind). These and other experiments point to a very different electron pairing mechanism than that seen in low-temperature superconductors. Once the pairing mechanism is understood, it will be easier to find materials with higher critical superconducting temperatures and better mechanical properties.

- *Magnetic Resonance Imaging (MRI) Without Magnets.* Striking, high resolution MRI images have been obtained without the need for high field magnets or high frequency detectors normally required for MRI. The breakthrough involves MRI enhancement by noble gases magnetically polarized (100,000 fold) through laser treatment. A new ultra-low-field MRI instrument now makes it possible to obtain extremely bright MRI pictures of polarized samples in the earth’s natural magnetic field, which is thousands of times weaker than fields obtained from traditional MRI magnets (which are bulky, expensive, and often hazardous). The new instrument has been used with localized injection of polarized xenon solutions into human blood to provide the first observations of the real-time process of xenon penetrating red blood cells. (Xenon is an inert gas and an FDA-approved anaesthetic.) This combination of techniques opens the way to provide high resolution MRI images of localized areas in animal and human subjects.

- *Discovery of New Materials Using LEGO.* Of the enormous number of combinations of elements in the periodic table, only a very small fraction are used in real materials. It is quite certain that materials with optimum properties for various applications have not yet been discovered. For example, high-temperature superconductivity occurs in ceramic compounds with a most unlikely combination of elements. A new strategy using fast computers and concepts from quantum mechanics has been developed to search for "winning combinations" of atoms to produce materials with improved physical properties. This approach -- Linear Expansion in Geometric Objects (LEGO) -- recognizes that even complex crystal structures can be viewed as a collection of simple geometric objects such as dumbbells, triangles, etc. By assigning each geometric object an energy value, computers can rapidly scan hundreds of thousands of candidates looking for the lowest overall energy and, therefore, the most stable structures. LEGO has already predicted several new intermetallic compounds missed through conventional approaches.

- *Electrically Conducting Nanoscale Ropes.* Incredibly light synthetic metals with a potential electrical conductivity 50-100 times better than copper per weight are being made from carbon nanotubes doped with metals. First discovered in 1991, nanotubes are a new class of materials formed from graphite-like sheets of carbon rolled into exquisitely small cylinders. They self organize in the vapor phase during growth to form well ordered crystalline bundles of individual nanotubes. The introduction of dopant atoms, such as potassium or lithium, into the open spaces between adjacent tubes within a rope can increase electrical conductivity significantly at room temperature. Doped nanotube ropes are also attracting increased interest as constituents of novel nanoscale device structures and as replacements for pure lithium metal in Li ion batteries.

- *Molecular Bricks for Nanotechnology.* Lightweight materials are commonly composed of polymers, which are long chains of atoms. The chains are difficult to order completely, which limits their functionality and durability. Researchers have recently demonstrated new possibilities for the design of polymers using nano-objects, which can be regarded as molecular bricks. These bricks, which might have shapes as diverse as those of nature's proteins, create a toolbox for the design of lightweight materials that could self assemble into structures with surprising functionality. Using the first elements of this toolbox, a spherical nanostructure has been created that has internally continuous channels; some channels transport water and ions, while others block water but accept organic substances. These nano-sponges could trap toxic metals from water streams.

- *What Makes Stainless Steel Stainless?* Corrosion damage is estimated to cost the U.S. 4.2 percent of the Gross National Product each year. Metals can be used in industrial and technological applications only when appropriately protected. In the case of stainless steel and many other metals, protection is provided by a thin oxide film that prevents further corrosion. However, the structure of these oxide films has remained a mystery despite decades of study. Recent research using surface-sensitive synchrotron x-ray diffraction with a combination of electrochemical experiments has now unambiguously determined that the oxide film on pure iron has a very fine-grained, nanocrystalline structure. Results for iron-chromium alloys (e.g., stainless steel) have shown that the oxide films are also nanocrystalline. This overturns the long accepted belief that stainless steel is corrosion resistant because its oxide film is non-crystalline. These surprising results provide a more realistic basis for understanding corrosion resistance and for the development of better corrosion protection coatings.

- *Do Cracks "Melt" Their Way through Solids?* Predicting and explaining why, how, and when solids fracture is a significant scientific challenge. The driving force for fracture is intensification of the local stress at a crack tip, yet the mechanism by which local strain is dissipated during crack propagation is not well understood. Can strain energy be dissipated via “local melting” around the crack tip? Recent computer simulations of crack formation predict this intriguing possibility. Simulations indicated that the melting in front of a crack tip can lead to catastrophic fracture. Using high-voltage electron microscopy, observations of moving crack tips in an intermetallic compound confirmed the prediction of the computer simulations and showed the development of melted and rapidly re-solidified regions adjacent to the crack tip. This new picture of fracture as a stress-induced melting process may lead to new approaches to stress-corrosion cracking in the automotive, aerospace, power generation, and ship building industries.

- *Smart Filters.* New materials with tailored pore sizes and pore chemistry can selectively remove deadly heavy metals -- such as mercury, lead, and silver -- from water. Researchers discovered that precise control over the amount of water in the pores of porous silica enabled the insertion of useful organic molecules on the walls of the pores. Using this knowledge, monolayers of organic sulfur compounds were bound to the internal surfaces of porous silica to prepare selective filter materials. The high surface area of the porous silica (a few grams have as much surface area as a football field) coupled with the bonding characteristics of the organic compounds results in high filtering capacity and high selectivity for specific contaminants. In addition, pore openings in the silica are designed to be too small for microbes to enter and digest the contaminants, later causing human illness from, for example, mercury contamination. The filter materials can purify highly contaminated water in a single treatment to a level that exceeds drinking water standards. The filters can also be recovered and reused after removing the contaminants.

- *A Line in the Sand.* Granular materials like gravel, salt, or dry chemicals are ubiquitous in our daily lives and central to many industrial processes, yet controlling their motion is both surprisingly difficult and not well understood. For example, granular material subjected to a driving force remains at rest until a minimum "critical force" is applied; then it moves in uncontrollable events like avalanches. Inefficiency in handling granular materials may result in the loss of up to 40 percent of the design capacity of industrial plants. In its retrospective of the last 50 years, *Physics Today* highlighted the emerging science of granular materials as a notable event of the last decade. Scientists have recently developed a theoretical approach to describe the motion of granular materials in a vibrating environment. This theory correctly describes the unexpected formation of stripe, square, and hexagon patterns on the surface of vibrated granular media and the formation of localized excitations called "oscillons." The theory also predicted how to control aspects of granular motion -- a prediction that was confirmed by experiment. The new theory brings the description and control of granular motion to a higher level of understanding and shows promise of substantial advances in basic granular science, which can lead to industrial applications that exploit the controlled motion of granular materials.

- *Vortex Matter -- A New Understanding of Magnetism in Superconductors*. Magnetic fields in superconductors are carried by "vortices." Each vortex consists of a tube of magnetic field surrounded by a circulating flow of electrons that move without resistance. It is this free flow of electrons that gives superconducting materials their special property. Recently, it has been shown that the system of magnetic vortices can take many forms analogous to the solid, liquid, and gaseous forms of ordinary matter. The analogy between the behavior of vortices and ordinary matter is so strong that a new term has entered the scientific vocabulary -- vortex matter. Vortex matter melts from a crystalline to a liquid state in much the same way that ice melts to water. The properties of vortex matter can be controlled over a wide range. For example, the density of vortices can be varied by a factor of 10,000 simply by changing the applied magnetic field. This remarkable control enables the study of many types of phenomena in vortex matter whose analogies in ordinary matter are difficult or impossible to observe. Thus, the identification and characterization of the melting transition in vortex matter has significant implications for phase transitions in ordinary matter, for understanding the electromagnetic properties of superconductors, and for developing applications of superconductivity.

Chemical Sciences

- *Landmark Experiment Challenges Combustion Models.* Combustion is perhaps the oldest technology in human experience, yet its complexity limits predictions of combustion processes in devices ranging from simple laboratory burners to automobile engines. The challenge is characterizing the influence of chemistry and fluid dynamics on one another. A simple experiment recently has demonstrated a major error in current models for combustion processes. The experiment allows the interaction of chemistry and turbulence to be examined in quantitative detail for the first time. A planar flame sheet is deformed by a puff of air generated by a small loudspeaker. Spectroscopic techniques are used to determine the concentrations of reaction intermediates as the flame sheet deforms. Comparisons of these experiments with computational simulations showed that the widely accepted chemical reaction mechanism for simple methane combustion is in error, thus, requiring a fundamental change in our models for combustion.

- *Fishing for Radioactive Actinides with Molecular Hooks.* The selection, separation, and removal of radioactive actinide ions from complex aqueous waste stream mixtures remain vexing technical issues. The development of new, improved separation approaches will result in significant cost savings for nuclear waste treatments as well as improve environmental safety and materials safeguard security. A new family of chelate agents or "chemical fish hooks" suitable for the reversible "catch and release" of trivalent actinide ions in highly acidic solutions has been designed, prepared, and characterized. The latest chelate derivatives show separation characteristics that are especially suited to practical, batch type waste treatments.

- *First Isolation of a Catalytic Oxidation Intermediate*. Despite worldwide efforts over the last 15 years on catalytic olefin oxidation, little progress has been made in extrapolating from ethylene (the smallest olefin) to larger olefins such as propylene. The key question -- the molecular mechanism of ethylene epoxidation (which gives us anti-freeze and polyester fibers) -- remains unresolved. Now, a combined experimental and theoretical tour de force has yielded the first definitive isolation and spectroscopic characterization of a stable intermediate in the catalytic process -- an oxametallacycle. Calculations were employed to determine the structure for the oxametallacycle on silver and to predict the infrared spectrum and molecular motions for that structure. Conclusive identification was provided by the excellent agreement between the predicted infrared spectrum and the experimental electron energy loss spectrum.

- *Liquid Crystalline Organic Semiconductors Discovered.* Liquid crystals change their optical properties as they transition between distinctive geometric states. Digital watch displays, for example, cycle between transparent and opaque forms. They, like other technologically important liquid crystals, are electrically insulating. Semiconducting crystals could have much broader application than insulating crystals, but large single crystals of these materials are difficult and expensive to produce. In a recent breakthrough, a family of liquid crystalline derivatives of perylene diimide was discovered that has semiconductor properties. The films of one compound self organize from a red, polycrystalline phase with randomly oriented crystallites into a black phase with highly ordered ribbon-like structure. The fluorescence intensity increases seven-fold during the transformation. This spontaneous change in photophysical properties makes this class of organic liquid crystals look very promising for future photoconversion applications.

- *Diode Lasers Detect Radiotoxic Isotopes.* Solid-state diode lasers, similar to those used in compact disc players, have been used in a new approach to detect the toxic radioisotope strontium-90, which received attention because of high levels found in milk after atomic weapons tests and the Chernobyl reactor accident. Diode lasers excite and efficiently ionize the strontium atoms; the resulting ions are detected using a mass spectrometer. The high efficiency allows the detection of less than one femtogram (femto = 10^{-15}, e.g., a single postage stamp compared to the area of Texas) of strontium 90. Furthermore, it is possible to selectively ionize the strontium 90 even in the presence of large excesses of the stable, naturally-occurring isotopes of strontium. Measurements can be performed in a few minutes as compared to the several weeks required previously for conventional radiochemical decay counting methods. Thus, this new approach should significantly improve the capabilities for near real-time monitoring of environmental restoration activities, nuclear weapons tests, reactor accidents, and the processing of nuclear fuels.

- *Photochemical Studies on the Light-Activated Drug Hypericin.* The popular herbal remedy St. John's wort contains the compound hypericin which, upon exposure to light, is toxic to tumors and HIV, the human AIDS virus. Now, the fundamental photochemistry of hypericin has been elucidated. A novel laser spectroscopic technique, fluorescence upconversion, was used to show definitively that the primary photochemical process is excited-state intramolecular proton or hydrogen transfer. Any incomplete proton or hydrogen atom transfers would acidfy the aqueous solution immediately surrounding hypericin, which may be of importance in its toxicity to viruses. The study is yet another example of the role that the physical sciences play in providing fundamental information relevant to a wide variety of subject areas.

Engineering and Geosciences

- *Remote Sensing of Fractures and Prediction of Failure in Rocks.* Long before catastrophic fracturing and failure of a material, sound waves transmitted through the material show a dramatic frequency shift. This shift has been documented before in fractured materials, but the observation of the shift *before* the formation of a continuous crack is a new discovery. Monitoring for the frequency shift can therefore be used to provide a warning of failure. The sound shifts to a lower frequency because the high-frequency sound (with shorter wavelengths) is preferentially absorbed or scattered. Because the frequency shift occurs prior to creation of a single fracture, there should be a network of oriented, disconnected features appearing prior to a crack that absorb or scatter the high-frequency sound in the same way as do observable cracks. Connected cracks in rocks provide pathways for water, oil, or pollutant flow. The growth of cracks can improve fluid flow or cause failure of well-bores, reservoirs, and tunnels or engineered structures; therefore, it is very important to understand how and when cracks form.

Energy Biosciences

- *The 1997 Nobel Prize in Chemistry.* Dr. Paul D. Boyer shared in the 1997 Nobel Prize in Chemistry for "elucidation of the enzymatic mechanism underlying the synthesis of adenosine triphosphate (ATP)." The energy captured from photosynthesis or released from respiration is converted into ATP, which is used for maintenance of cells, synthesis of cellular components, and other energy-requiring processes such as movement. ATP is frequently referred to as the "energy currency" of the cell. Dr. Boyer's work at the University of California at Los Angeles was supported in part by the Division of Energy Biosciences and its predecessor organizations from 1963 until 1993 under a project entitled "Energy Capture and Use in Plants and Bacteria."

- *Building Doors into Cells.* Before any molecule can enter a cell, it must first pass through the cell membrane—the thin, fat-containing film that covers all cells. The passage of most molecules through biological membranes is controlled by pores, defined openings made with specific proteins. The composition and structure of pore proteins can now be altered through genetic engineering. Changes in the size of the pore, the selectivity of the pore for letting different molecules pass through, and the pore's ability to open and close are three properties currently being studied by bioengineering new pore proteins. Successful attempts to engineer modified pore opening and closing properties have provided insight on how these processes can occur mechanistically as well as for developing new biotechnological applications. Among the potential products of this research are chemical triggers or molecular switches that can be used to create new sensors to detect harmful chemicals or viruses. Other potential applications are the development of small light switches and new drug delivery systems.

Scientific Facilities Utilization

The BES program request includes $311,035,000 to maintain support of the scientific user facilities. Within this overall level of support is a partial cost-of-living increase for facility operations and an increase in funding for the High-Flux Isotope Reactor at Oak Ridge National to continue activities related to the replacement of the beryllium reflector and associated beamline upgrades. The reduction in support for the scientific user facilities from that of FY 1999 is primarily a result of the decrease in R&D for the Spallation Neutron Source. Support for facility operations is maintained at as high a level as possible consistent with budgetary constraints. Research communities that have benefited from the BES supported Scientific Facilities Initiative 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 and related research in broad areas of the physical, chemical, materials, biological, and medical sciences. The SNS will be the world’s most powerful accelerator-based, pulsed neutron source producing 6-10 times more neutrons than any other such source. It 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.

The SNS will consist of a linear accelerator (linac)-ring system that will deliver short pulses of protons to a mercury target where neutrons will be produced by a nuclear reaction process called spallation. The high-energy neutrons so produced will be moderated (i.e., slowed down) to reduce their energies. The “moderated” neutron beams will then be used for neutron scattering experiments. Specially designed scientific instruments will use these pulsed neutron beams for a wide variety of investigations on all types of materials.

As the needs of our high-technology society have changed, so has the way we do R&D on new materials to meet these needs. It has become increasingly important to develop new materials that perform under severe conditions and yet are stronger, lighter, and cheaper. 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 applications. Neutron scattering will play a role in all forms of materials understanding 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 neutron science for fundamental discoveries and technological development is now universally acknowledged. The scientific justification and need for a new pulsed 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 MW spallation source that could be upgraded to significantly higher powers in the future.

The conceptual design of the SNS -- which was an interlaboratory effort involving Lawrence Berkeley National Laboratory in the ion source, Los Alamos National Laboratory in the linear accelerator, Brookhaven National Laboratory in the accumulator ring, and Argonne National Laboratory in targets and moderators -- was completed in June of 1997. The design conforms to the recommendations of the Russell Panel Report. The power will be in the 1 megawatt range or about six times that of the highest currently available worldwide, and the design will allow for significantly higher powers at a later stage. The design will further include moderators for neutrons with appropriate spectral and temporal characteristics in the epithermal, thermal, and cold energy ranges. There will be the potential for at least three target areas and for 30 to 40 instruments.

Agreements are in place with Rutherford Appleton Laboratory (England), the European Spallation Source project, and the Japanese Atomic Energy Research Institute to allow joint research and development. Furthermore, a Working Group on Neutron Sources has been established under the Megascience Forum of the Organization for Economic Cooperation and Development. A User Committee has been formed, consisting of distinguished members of the neutron science community, to provide input on instrumentation and on user needs.

FY 1999 funding provided for the start of Title I design activities, initiation of subcontracts and long-lead procurements, and continued critical research and development work necessary to reduce technical and schedule risks. FY 2000 funding of $214,000,000 is requested for the SNS

Project for detailed design (Title II) for the ion source, low-energy beam transport, LINAC structure and magnet systems, target assemblies, experimental instruments, and global control systems. Detailed design will be completed for several conventional facilities in preparation for the installation of major equipment in the following fiscal year; design will be completed 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 start for some conventional facilities including roads into the site, site preparation/grading, waste systems, and retention basins. Procurement for several significant equipment items such as dipole magnets, material for the target transport systems, and klystrons will begin. Project Management and Project Integration activities, which are exceptionally important during this phase of the project, will also be conducted. The Preliminary Safety Analysis Report (PSAR) will be completed during the fiscal year and work will begin on the final report. Additional information on the SNS project is provided in the SNS construction project data sheet, project number 99-E-334.

Facility Enhancements

BES will continue to support ongoing enhancements and maintenance activities of existing reactor and spallation neutron 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) The beryllium reflector at the High Flux Isotope Reactor at Oak Ridge National Laboratory is being changed. This is a scheduled maintenance operation that addresses the normal lifetime limitations of the beryllium reflector. Work was initiated in FY 1998 and will be completed in FY 2000. At the same time that the beryllium reflector, beam tubes and shutters, and monochrometer shields are replaced, several improvements will be made to instrumentation, beam tubes, and monochrometers. The improvements will provide increases in flux to the sample by factors of 2 to 3 times that of the Institute Laue Langevin, the world's best reactor neutron source. These improvements to HFIR were recommended by BESAC.

Partnerships for Academic-Industrial Research (PAIR) Program

The Partnerships for Academic-Industrial Research (PAIR) Program. Pending the results of an evaluation of ongoing awards, an additional $1,500,000 may be allocated to the PAIR program for a total budget of $3,000,000. This program is designed to encourage and facilitate research partnerships between academic researchers, their students, and industrial researchers. The PAIR program encompasses the entire range of research supported by the BES program. Grants are awarded on the basis of competitive peer review to university researchers for support of fundamental, long-term, high-risk work that is jointly defined by the academic and industrial research partners and that supports a student or postdoctoral fellow from the university, who will spend at least four weeks per year in the industrial setting.

Complex and Collective Phenomena Program

The program in Complex and Collective Phenomena. In FY 2000, an additional $4,500,000 will be allocated to the program in Complex and Collective Phenomena for a total budget of $7,500,000. Much of the research supported by the BES program and its predecessor organizations during the past 50 years has been devoted to solving very difficult problems in idealized, simple systems. The challenge now is to use that knowledge to understand complex systems. This initiative supports work at the frontiers of basic research. Work is intended to be revolutionary rather than evolutionary, and it is expected that it may involve multidisciplinary and/or interdisciplinary efforts. Further it is expected to bridge the gap between an atomic level understanding (reductionist view) and a continuum mechanics understanding (classical view) of complex and collective phenomena. Awards are made on the basis of competitive peer review to university and DOE laboratory researchers. The initiative is open to the entire range of disciplines supported by the BES program. Some important categories of studies that might be included within the initiative in Complex and Collective Phenomena are:

Materials that are beyond binary; that lack stochiometry; that are far from equilibrium; that have little or no symmetry or low dimensionality. Often properties and behaviors that we desire exist only in "non ideal compounds," i.e., those that are made from more than a few elements, made in non stoichiometric combinations, made far from equilibrium; or made in one or two dimensions. These classes of materials, which will dominate the next generation of energy technologies, pose new challenges and opportunities because of their complexity.

Functional synthesis. The ability to *predict* structure/function relationships remains elusive. Because function can be exquisitely sensitive to even minor changes in both composition and structure and because the number of combinations is virtually boundless, we are unable to predict what combinations of elements and arrangements of atoms give rise to desired properties such as superconductivity, magnetism, ductility, toughness, strength, resistance, catalytic function, or enzymatic function.

The control of entropy. To a scientist, entropy has a precise mathematical definition; however, to a nonscientist, entropy can be viewed as synonymous with disorder. A standard maxim in physics is that "the entropy of the universe tends to increase," i.e., things become increasingly disordered with time. Interestingly, most of our energy now comes from fossil fuels that were derived from photosynthesis — the ability of plants to reduce entropy locally by absorbing sunlight and converting carbon dioxide to lower-entropy hydrocarbons, polysaccharides, and other compounds. However, even though photosynthesis has been studied for decades, we still do not completely understand it nor have we been able to duplicate or improve on it. This one example of the control of entropy — the ability to mimic the functions of plants — remains one of the outstanding challenges in the natural sciences.

Phenomena beyond the independent particle approximation. Phenomena beyond the independent particle model — that by their nature are collective — challenge our understanding of the natural world and require major advances in theory, modeling, computing, and experiment. Collective phenomena include widely diverse phenomena in the gas and condensed phases, including Bose-Einstein condensation, high-temperature superconductivity, and electron correlation.

Scaling in space and time. Research in chemistry, materials, geosciences, and biosciences covers lengths from the atomic scale to the cellular scale to the meter scale and times from femtoseconds to millennia. We understand single atoms, molecules, and pure crystals fairly well; but, when we go beyond these simple systems to larger more complex systems, our understanding is limited. Understanding phenomena over wide time scales is also important — from femtoseconds in spectroscopy to decades in the regulatory system of plants to thousands of years in radioactive waste disposal.

Climate Change Technology Initiative

Overview

The FY 2000 budget contains two carbon related programs, each of which cut across several agencies. The first is the Climate Change Technology Initiative (CCTI). That part of the CCTI that is within the Office of Science is a joint activity between the Biological and Environmental Research (BER) and Basic Energy Sciences (BES) programs. The second program is the U.S. Global Change Research Program (USGCRP) that spans eleven agencies and is coordinated through the National Science and Technology Council's Committee on Environment and Natural Resources. Within DOE, the BER program plays the lead role in USGCRP activities. Although the two programs, CCTI and USGCRP, are synergistic, they are different. USGCRP research focuses on developing the fundamental understanding of the comprehensive climate system and the global and regional adaptations to it. The CCTI focuses on the underpinning fundamental science that will enable mitigation of climate change while maintaining a robust National economy. All research in the CCTI will be peer-reviewed fundamental scientific research; no funds will be devoted to policy studies.

Eighty-five percent of our Nation's energy results from the burning of fossil fuels, a process that adds carbon to the atmosphere — principally in the form of carbon dioxide — from the sequestered fossil reservoir. Because of the potential environmental impacts of increases in atmospheric carbon dioxide, carbon management has become an international concern and has become a focus of the Climate Change Technology Initiative. A comprehensive research and development program that meets the needs of the Climate Change Technology Initiative addresses the diverse aspects of this problem. The Office of Science is well positioned to make significant contributions to the many solutions needed for this problem, as it is set to build on the fundamental discoveries of its core programs and extend them to the new discoveries needed to make carbon management practical and efficient. Science core programs include research on both carbon and non-carbon energy sources and on both carbon sequestration and carbon recycling. These core activities can now be exploited in the generation of the carbon management science that will underpin the technologies of the future. The theme of efficiency in energy production and use must span the entire range of research activities. Research on carbon energy sources, and their impacts, is a focal point of interagency activity through the U.S. Global Change Research Program (USGCRP). Research on non-carbon energy sources is also a focal point of intra-agency activities and is led by the DOE Office of Energy Efficiency and Renewable Energy. The DOE Office of Science, through activities in both the Basic Energy Sciences (BES) program and the Biological and Environmental Research (BER) program, supports research that underpins both efforts.

A research program in carbon management would include:

- science for efficient technologies,
- fundamental science underpinning advances in all low/no carbon energy sources, and
- sequestration science.

Science has long-standing programs in fundamental research that already impact the three categories. In the BES program, funds in the amount of $19,504,000, are provided specifically for carbon management science in the Climate Change Technology Initiative. This work will be a natural extension of the complementary, ongoing work in several programs in Science, and it will build on the foundation of excellent and relevant research already underway. Focus areas will be those that build on strengths of the current Science programs and that promise maximum impact in the area of carbon management.

Immediate Impacts of Expanded Effort in Climate Change Technology

Additional science efforts will not only address an immediate societal problem, but they will also have a major effect on many scientific disciplines by advancing the state of knowledge and by training students in areas of research that are important to carbon management. For example, biochemistry, molecular and cellular biology, structural biology, and genome science will be impacted, because the production of fuels and chemicals by plants and microorganisms and the interconversion of greenhouse gases requires a better understanding of metabolism, of the structure and function of sub-cellular components, and of enzymes. Similarly, the state-of-the-art in biochemistry, molecular biology, and ecology will be impacted. All of these biological processes are important in understanding the role of marine microorganisms in sequestering carbon. Improvements in combustion to reduce carbon emissions require a fundamental understanding in chemical dynamics and theoretical chemistry and physics. Conversion of sunlight to energy requires an understanding in many areas of science, including photochemistry, photosynthesis, metabolism, and solid state physics. The search for increased efficiency in energy production and use requires fundamental knowledge in ceramics, metals, polymers, solid state chemistry, and condensed matter physics for materials that can withstand higher temperatures, have lower coefficients of friction, and are stronger and lighter. Enhanced recovery of fuel resources and of disposal of carbon dioxide requires a fundamental understanding of geometric, structural, and hydrologic properties of reservoirs and of multiphase, nonlinear transport of fluids in porous and fractured structures. Crosscutting programs in nano- and meso-phase materials involve research at the forefront of materials science, chemistry, engineering, surface science, and semiconductor physics.

The new research efforts supporting advances in low/no carbon energy technologies, as well as existing activities, will be closely coordinated with DOE's technology programs and will provide the knowledge base for the development of advanced technologies to reduce carbon dioxide emissions. Many of the activities will impact the Office of Energy Efficiency and Renewable Energy (EE) and the energy and transportation industry by providing options for increasing efficiency in automobiles by reducing weight; for increasing efficiency in the use of electricity by increasing the efficiency of electric motors and generators with better magnets; for increasing efficiency in the transmission of electricity by using superconductors; and for reducing energy consumption in manufacturing with improved sensors, controls, and processes. Much of this research program will provide the knowledge base needed to increase the use of renewable resources with research aimed at understanding the metabolism of carbon dioxide and the metabolic pathways to the production of methane and other biofuels. Other aspects of the research program impact the Office of Fossil Energy (FE) by providing a foundation for effective and safe underground sequestration, new materials, a better understanding of combustion, and improved catalysts.

Funding will be provided for areas of research in carbon cycle management including appropriate areas that will be jointly identified and implemented by the Biological and Environmental Research and Basic Energy Sciences programs. Solicitations will be used for individual research projects. Additionally, proposal notifications may be developed jointly with the DOE energy technology programs with the intention of establishing multi-disciplinary centers at universities and national laboratories that will use the full capabilities of the institutions for a research program in carbon cycle management encompassing, for example, topics in the following areas: integration and assessment; separations; efficiency; clean fuels; bioenergy; storage and conversion; enhanced natural terrestrial cycles; and enhanced use of major scientific user facilities to support carbon management research.

Interagency Environment

The Office of Science program in fundamental science supporting energy technologies will be closely coordinated with, and synergistic to, the activities in its sister agencies (e.g., NASA, NSF, NOAA, USDA, DOI, and EPA) within the USGCRP. Through its leadership role in decade to century climate prediction, the Office of Science has developed the research capability for comprehensive and large scale modeling of carbon dioxide impacts on climate, on ecology, and on ocean sciences, and this expertise is augmented by complementary activities in the other agencies. Similarly, the network of carbon flux measurements and ecological experiments that the Office of Science has developed serve as a backdrop to those of many other agencies, and the state-of-the-art can thus be pushed ahead more rapidly by capitalizing on the more rapidly growing base of knowledge. The Office of Science also has a leadership role within the USGCRP on consequence evaluation of increased greenhouse gases in global climate change, including integrated assessments that address both scientific and societal (including economic) impacts of carbon management. Finally, through its pre-eminent role in the Human Genome Program and its development of the complementary Microbial Genome Program, the Office of Science program is ideally placed to support research that will focus on the application of genetic information of microorganisms to increase metabolic efficiency related to both carbon dioxide and conversion to fuels through photosynthesis.

BES Activities

Climate Change Technology Initiative

	(dollars in thousands)	
	FY 1999	FY 2000
Materials Sciences	1,708	3,415
Chemical Sciences	2,197	4,394
Engineering and Geosciences	1,464	6,822
Energy Biosciences	2,436	4,873
Total	7,805	19,504

As noted above, an inclusive climate change technology research and development program must address diverse aspects of the problem including: (1) carbon recycling; (2) improved efficiency in the use of fossil carbon energy sources; (3) new and improved non-carbon energy sources; and (4) carbon dioxide sequestration. The BES program has long supported fundamental research that impacts these categories and has particularly strong programs related to the first three. A comprehensive program in issues relating specifically to carbon management, therefore, finds a natural home with the scientific communities supported by BES.

Focus areas 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, research emphasizes atomic and molecular level understanding of chemical processes to enable predictive capability. A major component of the research will aim 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 will include research to: (1) understand the mechanical stability of porous and fractured reservoirs/aquifers; (2) understand multiphase fluid flow within the aquifers; and (3) understand the 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.

All of the BES activities in CCTI are closely related to DOE's technology programs and will provide the knowledge base for the development of advanced technologies to reduce CO_2 emissions. When combined with the complimentary activities within the Biological and Environmental Research program, this initiative will lead to the comprehensive carbon management research program described above.

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 support 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 totalling $6,300,000 in this category also addresses the 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, photoassisted 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.

BES engages in appropriate partnerships to make the results of the BES research widely known and used. Examples include partnerships with the DOE technology offices and with other federal agencies. As a result, BES engages in many joint activities. For example, in photovoltaics, the Office of Energy Efficiency and Renewable Energy (EE) and BES together sponsored a workshop in 1993. Based on this workshop, a jointly funded project was started at NREL that resulted in record-breaking photovoltaic efficiencies. In general, research activities in biomass, wind energy, photovoltaics, hydrogen, and solar photoconversion are coordinated with EE through Coordinating Committees in the Department, through ad hoc meetings, through workshops, and through joint funding at universities and at the Department's laboratories.

In November, 1997, more than 30 program staff from the Office of Science (SC) — primarily from BES — and from EE Offices of Utility Technologies and Transportation Technologies met to discuss programs in the areas noted above. The EE programs involved include those of photovoltaic energy systems, solar thermal, hydrogen technologies, wind technologies, biomass power, and biofuels (transportation). Follow on one-on-one meetings between program managers of both offices are now being held for identification of research needs, gaps and areas of opportunity of possible joint program development. For example, in May 1998, BES program staff participated in a Workshop on Biohydrogen Production sponsored by EE's Hydrogen program and by the Engineering Directorate at NSF; BES staff further provided reviews of EE projects in the area of biological hydrogen production and recommendations for the overall direction of that program. Another outcome of the November 1997 meeting has been the re-establishment of a Department-wide technical committee in the area of bioenergy which includes program representatives from BES and EE and also from the Office of Environmental Management (EM) and the Office of Fossil Energy (FE). The purposes of the revitalized DOE Bio-Energy Coordinating Committee (BECC) are to: (a) achieve effective coordination of all DOE bio-energy research and development; (b) assure optimum use of DOE's existing expertise in the field of bio-energy research and development; and (c) achieve the most rapid communication among DOE program representatives of new developments, opportunities, and issues in the areas of bio-energy research, development, demonstration and commercialization. In a related effort, BES and EE's Office of Fuels Development are drafting a joint research topic on biofuels for the FY1999 SBIR Program Solicitation.

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 $346,000 and $313,000 for estimated contractor clearances in FY 1999 and FY 2000, respectively, within this decision unit.

Scientific Simulation Initiative

This budget also includes the BES program's contribution to DOE's Scientific Simulation Initiative (SSI), an integrated effort bringing together computational and communication resources, focused research in scientific disciplines, and research in computer science and other enabling technologies to solve the complex problems that characterize DOE's scientific research needs. The SSI couples research in advanced scientific applications in the programs of the Office of Science (SC) with research in computer science and enabling technologies and advanced computing and communications facilities. It is a joint program between the Computational and Technology Research (CTR) program and the other programs in SC. The overview of the integrated program is given in the overview of the CTR budget; however, the specific contributions of the BES program are described below.

BES, through its Chemical Sciences subprogram manages the SSI Combustion Systems integrated applications effort. BES's participation in the SSI also represents an important contribution to the broader Presidential initiative in information technology. The Chemical Sciences subprogram has been involved in combustion research for over two decades. The goal of this research effort is to develop, through simulation and modeling, a sufficiently deep and detailed understanding of combustion processes to accelerate the development, characterization, and validation of design tools for advanced combustion devices. Eighty-five percent of current U.S. energy use is derived from the combustion of fossil fuels. This dependence on fossil fuels is not likely to change in the coming decades. For transportation technologies alone, preliminary calculations suggest that improvement in direct-injection diesel thermal efficiency of 35% is possible, which could result in energy savings of 3.7 quads or $26 billion and reductions of carbon dioxide ($CO_{2)}$ emissions of 250 million tons per year. Combustion has been and remains one of the primary causes of lowered air quality in urban environments. Providing the knowledge that can lead to improved efficiency of the fossil fuel combustion process while reducing unwanted emissions remains one of among the highest priorities in the Nation's research portfolio. High fidelity combustion simulation and modeling may well be the path to significant breakthroughs in the ability of engineers to characterize, and therefore optimize and control, all aspects of combustion devices.

At present, engineers have neither sufficient knowledge nor the computational tools to understand and predict the chemical outcome of combustion processes. The design of combustion devices remains an Edisonian process dependent on intuition, experience, and time consuming trial and error. Computational models to guide the design process currently are of limited use because of the extraordinary complexity of the combustion process. This complexity derives from:

- the hundreds of chemical reactions that comprise combustion chemistry;
- fluid dynamics with turbulence scales covering 6 orders of magnitude; and
- interactions between chemistry and fluid dynamics involving time and spatial scales that cover 12 orders of magnitude.

The anticipated accomplishments of this research effort will allow the complete characterization of the chemistry and fluid dynamics of combustion processes and systems. The computational tools developed under this program, along with the new level of understanding of complex combustion phenomena, will allow engineers to design a new generation of combustion devices optimized for energy efficiency and pollution reduction.

The combustion modeling and simulation component of the SSI will be managed in a manner consistent with the way BES manages other projects and facilities. A program manager in the Office of Basic Energy Sciences will be appointed to be responsible for the effort. This manager will be assisted by a technical management and coordination office located at one of the DOE laboratories whose role is to ensure that the subelements remain tightly integrated. Research teams at laboratories and universities, as well as the technical management and coordination office, will be competitively selected in response to a published announcement and following peer review.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Basic Energy Sciences					
Research					
Materials Sciences	381,828	417,216	-2,530	414,686	407,636
Chemical Sciences	196,127	209,582	-2,745	206,837	215,577
Engineering and Geosciences	40,151	44,413	-1,674	42,739	37,545
Energy Biosciences	26,710	32,489	-2,627	29,862	31,226
Subtotal, Research	644,816	703,700	-9,576	694,124	691,984
Construction	7,000	105,400	0	105,400	196,100
Subtotal, Basic Energy Sciences	651,816	809,100	-9,576	799,524	888,084
Use of Prior Year Balances	-4,852 [a]	-4,002[a]	0	-4,002[a]	0
General Reduction for Policy Papers for CCTI		-8,000	8,000	0	0
General Reduction		-1,576	1,576	0	0
Total, Basic Energy Sciences	646,964 [b]	795,522	0	795,522	888,084

Public Law Authorization:

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

[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 $14,622,000 which has been transferred to the SBIR program and $877,000 which has been transferred to the STTR program.

Funding by Site

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	23,613	24,673	25,906	+1,233	+5.0%
National Renewable Energy Laboratory . . .	4,515	4,193	3,744	-449	-10.7%
Sandia National Laboratories	28,764	26,600	22,008	-4,592	-17.3%
Total, Albuquerque Operations Office	56,892	55,466	51,658	-3,808	-6.9%
Chicago Operations Office					
Ames Laboratory	18,659	17,114	16,967	-147	-0.8%
Argonne National Laboratory, East	139,894	143,436	145,096	+1,660	+1.2%
Brookhaven National Laboratory	76,722	77,586	77,331	-255	-0.3%
Princeton Plasma Physics Laboratory	700	675	0	-675	-100.0%
Total, Chicago Operations Office	235,975	238,811	239,394	+583	+0.2%
Idaho Operations Office					
Idaho National Environmental and Engineering Laboratory	3,478	3,609	3,020	-589	-16.3%
Oakland Operations Office					
Lawrence Berkeley National Laboratory . . .	62,160	62,553	62,095	-458	-0.7%
Lawrence Livermore National Laboratory . .	5,933	6,044	5,236	-808	-13.4%
Stanford Linear Accelerator Facility (SSRL)	21,684	22,686	21,968	-718	-3.2%
Total, Oakland Operations Office	89,777	91,283	89,299	-1,984	-2.2%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science & Education . .	2,003	1,258	1,541	+283	+22.5%
Oak Ridge National Laboratory	110,219	217,848	302,898	+85,050	+39.0%
Thomas Jefferson National Accelerator Facility	200	0	0	0	0.0%
Total, Oak Ridge Operations Office	112,422	219,106	304,439	+85,333	+38.9%
Richland Operations Office					
Pacific Northwest National Laboratory	12,868	12,788	12,947	+159	+1.2%
All Other Sites [a]	140,404	178,461	187,327	+8,866	+5.0%
Subtotal, Basic Energy Sciences	651,816	799,524	888,084	+88,560	+11.1%
Use of Prior Year Balances	-4,852 [b]	-4,002 [b]	0	+4,002	+100.0%
Total, Basic Energy Sciences	646,964 [c]	795,522	888,084	+92,562	+11.6%

[a] Funding provided to laboratories, universities, industry, other Federal agencies and other miscellaneous contractors.

[b] 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.

[c] Excludes $14,622,000, which has been transferred to the SBIR program and $877,000, 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 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 leading experts on magnets, superconductors, and quasicrystals that incorporate rare earth elements. Recent innovations include the use of a rare earth alloy and the magnetocaloric effect to achieve efficient refrigeration without gases that are harmful to the atmosphere. The BES Chemical Sciences subprogram supports studies of heterogeneous electron transfer in self-assembled monolayers, 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 continues to provide leadership in analytical chemistry with strength in organometallic based catalysis and heavy metal extraction chemistry important to high level wastes.

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 in broad areas of materials, chemical, and geosciences, and it is 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 batteries and coal chemistry; 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 centers 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 by the Secretary of Energy, 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. 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 **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 in 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 two BES supported user facilities -- the National Synchrotron Light Source (NSLS) and the High Flux Beam Reactor (HFBR).

The Materials Sciences subprogram emphasizes experiments that make use of the NSLS and the HFBR. 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 centers for pulsed radiolysis research at BNL. With the recent completion of a new innovative short-pulse radiation chemistry facility, BNL is well poised to contribute significantly to radiation sciences research for the next decade. There is also a forefront research project 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 and lipid metabolism 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 1998, over 600 students who earned doctorate degrees used the NSLS in their thesis research.

The **High Flux Beam Reactor**, commissioned in 1965, is a heavy-water cooled and moderated reactor designed to produce neutrons for scattering. In contrast to most reactors, which are designed to minimize the escape of neutrons from the core, the HFBR was expressly designed to maximize the number of neutrons available in external beams. The HFBR supports a range of neutron-based research in solid-state and nuclear physics, chemistry, and structural biology. The reactor's 9 beam tubes deliver neutrons to 15 experimental facilities. Before the HFBR was put in standby mode in December, 1996, about 250 researchers conducted experiments at the facility annually. The HFBR will continue to be maintained in this standby mode while the Department evaluates options for its future.

Idaho National Environmental and Engineering Laboratory

Idaho National Engineering and Environmental 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, 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; and the structures of magnetic, optical, and electrical thin films and coatings. In the Center for Advanced Materials, research is conducted in the processing, mechanical fatigue, and high-temperature corrosion of structure ceramics and ceramic coatings; the synthesis, structure and properties of advanced semiconductor and semiconductor-metal systems; polymers; surface science and catalysis; and structure, development and magnetic properties of high performance metals and alloys. The Chemical Sciences subprogram has long excelled in 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 excellence 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 Sourc**e, 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 a new concept in catalysis, that of 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 an 800 MeV proton linac that is the basis for 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. 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 comprises a high-power 800-million-electron-volt 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 30 Tesla magnet is being developed for use with neutron scattering.

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 this 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 synthesis related to catalysis and to advanced battery research addressing high-efficiency, thin-film cathodes based on doped vanadium and manganese oxides. The BES Energy Biosciences subprogram funds programs to examine the mechanisms of photosynthetic oxygen evolution.

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 writing of annual BES subprogram summary books, the administration of topical scientific workshops, and provides support for other activities such as for the review of the Spallation Neutron Source Conceptual Design Report.

ORISE manages the **Shared Research Equipment Program** (SHaRE) at ORNL. The SHaRE Program has made 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 and Engineering Development Center (REDC). ORNL also leads the five-laboratory collaboration that will design and construct 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 programs such as the energy efficiency program in superconductivity. Research is supported 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 Facility.

The Chemical Sciences subprogram supports research in analytical chemistry, particularly in the area of mass spectrometry, separations 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 crustal rocks. Engineering research supports the Center for Engineering Systems Advanced Research with emphasis in 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.

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 experiment 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 are high-resolution laser spectroscopy for analysis of trace metals on ultra small samples, understanding 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 funds 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 focussed 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/A), with sites in Livermore, California (SNL/L), 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/A are relevant to the overall mission of the laboratory. Included among these are projects on the processing and properties sol-gel chemistry of ceramic coatings; 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/L.

The BES geophysics research effort at SNL/A 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/L 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 25 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 world leaders in photoemission studies of high-temperature superconductors and in x-ray scattering.

Thomas Jefferson National Accelerator Facility

Thomas Jefferson National Accelerator Facility (TJNAF) is a program-dedicated laboratory (Nuclear Physics) located on 273 acres in Newport News, Virginia. The Basic Energy Sciences program funds a research project at TJNAF related to fourth generation light sources based on linac-driven free electron lasers.

All Other Sites

The BES program funds research at 135 colleges/universities located in 43 states. This line also includes funding of 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, metals and ceramics 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.

Climate Change Technology Initiative. Research routes to improved carbon management in support of the Climate Change Technology Initiative include improved heat and corrosion resistant alloys to increase the efficiency of power generation, reducing energy losses in motors via improved magnetic materials, and displacing fossil fuels with higher-efficiency photovoltaic cells.

Performance Measures

- Continue Partnerships for Academic-Industrial Research where peer reviewed grants are awarded to university researchers for fundamental, high-risk work jointly defined by the academic and industrial research partners.
- Continue fabrication of instrumentation for the short-pulse spallation source at the Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Materials Sciences Research	195,752	187,793	188,342	+549	+0.3%
Facilities Operations	186,076	217,104	209,599	-7,505	-3.5%
SBIR/STTR	0	9,789	9,695	-94	-1.0%
Total, Materials Sciences	381,828	414,686	407,636	-7,050	-1.7%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
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 dimensionally restricted forms (films, dots) of materials. This activity provides world-class scientific user facilities to the Nation through the operation of four complementary and network interfaced electron beam microcharacterization user centers. These centers contain a variety of highly specialized instruments that complement each other in terms of their ability to characterize localized atomic positions and configurations, chemical gradients, interatomic bonding forces, etc. Major activities in FY 2000 will be responsive to the increasing demand for advanced facilities and models with capabilities to characterize and interpret the atomic structure, composition, bonding, and physical properties of materials with improved resolution and accuracy. Capital equipment needs for FY 2000 are expected to relate to facility refurbishment and upgrade.	24,455	25,655	25,390
■ **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			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
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 2000 will include continued development of experimental techniques and methods for the characterization of properties, the advancement of models and theories for interpretation, and the design and investigation of new materials and material structures. Capital equipment is needed for mechanical testing machines, especially with high-temperature capabilities, furnaces, and characterization equipment.	15,223	15,965	15,800
■ **Physical Behavior:** These activities support 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 2000 will continue fundamental studies of the mechanisms governing material response to aqueous, galvanic, and high-temperature gaseous corrosion; the processing and investigation of semiconductor materials and structures leading to enhanced solar energy conversion efficiencies; crystal defects, grain boundaries and interfaces for high-temperature superconductors; mechanisms controlling material response to hostile environments; and the structure and behavior of ceramic electrolytes for advanced fuel cells. Capital equipment is needed for corrosion studies and for electronic and spectroscopy instruments for the characterization of electronic, optoelectronic properties, and electrical properties of semiconductors, superconductors, and fuel cell electrolytes.	13,562	14,225	14,078

	(dollars in thousands) FY 1998	FY 1999	FY 2000
■ **Engineering Behavior:** These activities support basic research in the engineering behavior of materials. The research includes the synthesis and processing of materials with new or improved behavior, for minimization of waste, and with hard and wear resistant surfaces to reduce friction and wear; 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; 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 that makes available small quantities of specialized research quality materials for research purposes that are not commercially or otherwise available. Major activities for FY 2000 will include continued work on design of new material compositions and structures, synthesis and processing new and enhanced materials, and characterization and interpretation of material behavior. Capital equipment includes furnaces, lasers, processing equipment, plasma and ion sources, and deposition equipment.	20,211	21,205	20,985
■ **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 2000, measurements			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
of particular interest will include neutron and x-ray scattering from materials which exhibit complex phenomena resulting from 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 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 such items as detectors, monochromators, mirrors, and beamline instrumentation.	18,739	19,700	19,495

- **Experimental Condensed Matter Physics:** This activity supports fundamental experimental research in condensed matter physics. This 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 instruments including magnetic force microscopy, electron microscopic techniques, and innovative applications of laser spectroscopy are major

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
components 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. The major efforts in FY 2000 will include continued support for investigations of materials with increasingly complex behavior, composition and structures with strongly competing interactions among the electronic charge and spin, and the crystalline lattice. A major new activity will be the synthesis and fabrication of unusual materials systems with pulsed laser ablation epitaxy, self-organized structures, and engineered materials and structures to provide insight into unusual behavior. Capital equipment is provided for items such as lasers, scanning tunneling microscopes, electron detectors for photoemission experiments, sample chambers, superconducting magnets and computers.	26,147	27,450	27,165

- **Condensed Matter Theory, Particle-Solid Interactions, and Engineering Physics:** This activity supports basic research in theory and simulations, the use of ion beams to modify the properties of materials, and engineering applications. The theory activity complements much of the experimental work by guiding and stimulating experiments. The centers are group thrust areas in which individual scientists from widely different backgrounds work together to work on common research areas or making use of a common research facility. Included among these are the Center for X-ray Optics and the Center for Advanced Materials at LBNL and the Surface Modification and Characterization Facility at ORNL. Additionally, the design and construction of new, unique research instruments, such as the 100 Tesla Pulsed Field Magnet and the actinide photoelectron spectrometer at LANL, are supported in this activity. The emphasis in engineering physics is on the use of fundamental science to advance technology. Engineering physics includes activities

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
such as the application of sound waves for refrigeration; the fabrication of small, machined structures using x-rays; and the development of new, electron microscopy techniques such as the Z-contrast electron microscope at ORNL. This activity is science driven. Capital equipment is provided for items such as computer work stations, sample chambers, and high resolution electron microscopes. BES will provide opportunities for college faculty and students to spend time at DOE laboratories, to participate in world-class research projects. Faculty/Student Science Teams will visit our labs during the academic/summer semesters, be involved in conducting research, writing proposals, utilizing technology and pursuing techncial or scientific careers. Primary goals of the Science Teams are to build long-term partnerships among DOE laboratories and provide faculty/students with a deeper understanding of DOE science associated needs for research and development. Funds will be provided to pay for faculty/student stipends, travel, housing, and subsidize laboratory scientists' time for this activity ($1,947,000).	19,553	20,555	22,341
■ **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 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			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
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, electrode-electrolyte interfaces, catalysis, surface science and synchrotron x-ray micro-characterization have stimulated increased emphasis for these areas. 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.	23,547	24,715	24,458
■ **Experimental Program to Stimulate Competitive Research:** This activity supports basic research spanning the entire range of research supported by the Department in states that have historically received relatively less Federal research funding. The EPSCoR program supports research cluster activities at nine EPSCoR states through block grants and to individual investigator projects in all EPSCoR states and Puerto Rico. The EPSCoR states include Alabama, 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. 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 2000, this program will include new work that will make use of the DOE National Laboratories and the world-class facilities at these labs. This program will be science-driven and will support the most meritorious proposals based on peer review. Workshops and discussions have been held with representative scientists from EPSCoR states to acquaint them with the facilities and personnel at the DOE Laboratories.	6,815	6,815	6,815

EPSCoR Distribution of Funds by State

(dollars in thousands)

	FY 1998 Actual	FY 1999 Estimate	FY 2000 Estimate
Alabama	800	825 [a]	75
Arkansas	50	100	100
Idaho	50	100	100
Kansas	50	91	95
Kentucky	800	650 [a]	200
Louisiana	814 [a]	152	146
Maine	150	750 [a]	0
Mississippi	0	50	50
Montana	800 [a]	75	75
Nevada	850	855 [a]	96
North Dakota	0	47	46
Oklahoma	0	100	100
Puerto Rico	800	800 [a]	50
South Carolina	250	800	800
South Dakota	50	50	50
Vermont	25	25	25
West Virginia	100	100	100
Wyoming	800	800	800
Other	426 [b]	445 [b]	3,907 [b]
Totals	6,815	6,815	6,815

[a] In FY 1998 the funding commitments for awards to the States of Louisiana and Montana expire. In FY 1999, the funding commitments to the States of Alabama, Kentucky, Maine, Nevada, and Puerto Rico will expire.

[b] Includes technical support for the Experimental Program to Stimulate Competitive Research (EPSCoR). Uncommitted funds in FY 2000 will be competed among all EPSCoR states that do not have active Research Implementation Awards to begin new Research Implementation Awards.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **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	4,500	6,000
■ **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 $5,900,000 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.	0	3,500	2,400
■ **Replacement of High Flux Isotope Reactor Monochrometer Drums.**	0	1,800	0
■ **Spallation Neutron Source (SNS):** Conceptual design of the Spallation Neutron Source (SNS) was completed in FY 1997. FY 1998 funding will support continued Pre-Title I research and development on the SNS. Beginning in FY 1999, SNS research funding in support of construction is reflected in the facility operations section of this budget.	23,000	0	0
■ **Climate Change Technology Initiative:** Basic research in carbon management for the Climate Change Technology Initiative will focus on three areas: high temperature materials, magnetic materials, and semiconductor materials. A major goal in a carbon management program is the derivation of materials that can withstand higher temperatures for more efficient combustion and for improved properties in applications. Research will focus on attaining an atomic-level understanding and a predictive capability for bulk metallic glasses, which have the potential to make significant contributions in corrosion and wear resistance in fossil fueled power plants, and on structural ceramics, which will be used in high temperature applications such as engine components. Additional work will focus on a fundamental understanding of the			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
surface physics and chemistry of oxide layers, which is expected to produce alloys and coatings that have improved corrosion resistance at high temperatures. A second goal is the derivation of magnetic materials to reduce energy loss during use. Research on the microstructure of permanent magnetic materials to understand the optimum grain structure is expected to result in stronger magnets, and research in the processing of magnetic materials is expected to optimize magnetic properties. Taken together, research in magnetic materials is critical to energy efficiency, since electric motors consume about two-thirds of U.S. electric power. A final goal in the areas of materials sciences is 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. The research will focus on improving the efficiency of the conversion of light to electricity. For example, research in the physics of quantum confinement might lead to new nanoscale structures that can be tuned to absorb the full spectrum of sunlight, which, when coupled to electron transport structures, would provide new ways to convert sunlight to electricity.	0	1,708	3,415
Total, Materials Sciences Research	195,752	187,793	188,342

Facilities Operations

- **Operation of National User Facilities:** The facilities included in Materials Sciences are: National Synchrotron Light Source, High Flux Beam Reactor (currently not operating), 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 construction of the Spallation Neutron Source is also included. The facility operations budget request, which includes operating funds, capital equipment, and Accelerator and Reactor Improvements (AIP) funding under $5,000,000, is

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
provided in a consolidated manner later in this budget. AIP funding will support additions and modifications to accelerator and reactor facilities which are supported in the Materials Sciences subprogram. Included in the AIP funding are funds for the HFIR upgrade. Capital equipment is needed at the facilities for items such as beam monitors, interlock systems, vacuum systems, beamline front end components, monochromators, 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.	186,076	217,104	209,599

	(dollars in thousands)		
Facilities	FY 1998	FY 1999	FY 2000
National Synchrotron Light Source	23,047	24,094	24,523
High Flux Beam Reactor	22,986	22,568	22,580
Intense Pulsed Neutron Source	11,230	11,982	11,985
Stanford Synchrotron Radiation Laboratory	4,077	3,946	4,029
Manuel Lujan, Jr. Neutron Scattering Center	6,588	7,397	7,547
Advanced Light Source	30,708	31,166	31,732
Advanced Photon Source	82,368	86,226	87,703
Spallation Neutron Source	0	28,600	17,900
High Flux Isotope Reactor	3,972	0	1,600
Partial Offset to Science General Reduction Applied to BES	1,100	1,125	0
Total, Facilities	186,076	217,104	209,599

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
SBIR/STTR Funding			
■ In FY 1998 $8,696,000 and $522,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.	0	9,789	9,695
Total, Materials Sciences	381,828	414,686	407,636

Explanation of Funding Changes From FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Materials Sciences Research	
■ Decrease in research for structure of materials.	-265
■ Decrease in research for mechanical behavior and radiation effects.	-165
■ Decrease in research for physical behavior.	-147
■ Decrease in research for engineering behavior	-220
■ Decrease in research for neutron and x-ray scattering.	-205
■ Decrease in research for experimental condensed matter physics.	-285
■ Decrease in materials research for condensed matter theory, particle-solid interactions, and engineering physics.	-161
■ Increase in funding will provide opportunities for college faculty and students to spend time at DOE laboratories to participate in world class research projects.	+1,947
■ Decrease in research for materials chemistry.	-257
■ Increase in capital equipment for LANSCE instruments	+1,500
■ Decrease in capital equipment funds for extension of HB-2 beam tube at HFIR for thermal neutron scattering because of completion of scheduled activities	-1,100
■ Decrease in capital equipment funds for monochromator drums on HB-1 and HB-3 because of completion of scheduled activities	-1,800
■ Increase support for Climate Change Technology Initiative.	+1,707
Total, Materials Sciences Research	+549

	FY 2000 vs. FY 1999 ($000)
Facilities Operations	
■ Decrease in SNS research and development funds because scheduled activities supporting construction are nearing completion	-10,700
■ Slight increase in support for the operation of major scientific user facilities. . .	+1,595
■ Increase in AIP funds for HB-4 beamline enclosure at HFIR.	+ 1,600
Total, Facilities Operations	-7,505
SBIR/STTR	
■ Decrease SBIR/STTR funding due to decrease in operating expenses.	-94
Total Funding Change, Materials Sciences	-7,050

Chemical Sciences

Mission Supporting Goals and Objectives

The Chemical Sciences subprogram has two major components. The disciplinary areas within each component are connected to and address needs of the principal DOE and BES mission goals and objectives. One major component is comprised of atomic, molecular and optical (AMO) physics; chemical physics; photochemistry; and radiation chemistry. 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. Completely unanticipated benefits from this research often result. For example, research supported by the Chemical Sciences subprogram on small atomic clusters led to the discovery of the new forms of carbon named the fullerenes, typified by C_{60} (buckminsterfullerene). The 1996 Nobel Prize in chemistry was awarded to the scientists who made this discovery. The other major component of the research program is comprised of inorganic chemistry, organic chemistry, analytical chemistry, separations 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 and to new catalysts for the production of fuels and chemicals, better analytical methods in a wide variety of applications in energy processes and environmental sciences, 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.

Climate Change Technology Initiative. The chemical physics and photochemistry components of the research program provide the underlying chemical science needed to address carbon management. These areas enable more efficient combustion and new understanding of the photochemical conversion of CO_2 and the direct conversion of solar radiation to electricity. The component of the research program, comprised of separations science, physical chemistry and inorganic chemistry, provides the basis for new and improved catalysts for conversion of fuels to carbon dioxide and hydrogen, potentially for carbon dioxide conversion to chemicals, separation of the conversion components, and new electrochemical energy production and storage systems.

Scientific Simulation Initiative. This subprogram includes the Combustion Systems Integrated Applications component of DOE's Scientific Simulation Initiative (SSI), an integrated effort bringing together computational and communication resources, focused research in scientific disciplines, and research in computer science and other enabling technologies to solve the complex problems that characterize DOE's scientific research needs.

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Chemical Sciences Research	128,452	132,750	139,230	+6,480	+4.9%
Facilities Operations	67,675	68,928	71,430	+2,502	+3.6%
SBIR/STTR	0	4,672	4,917	+245	+5.2%
Congressional Direction	0	487	0	-487	-100.0%
Total, Chemical Sciences	196,127	206,837	215,577	+8,740	+4.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000

Chemical Sciences Research

- **Photochemistry and Radiation Research:**
  - The photochemistry research program investigates, at the molecular level, fundamental processes that capture and convert solar energy. Fundamental concepts of light-induced charge separation at the molecular level are developed for application to photodriven endothermic reactions for the conversion of light energy to chemical energy. In addition, photochemistry presents opportunities for altering chemical reaction pathways so that high volume industrial intermediates and specialty chemicals can be produced by less polluting processes. The program encompasses organic and inorganic photochemistry, electron and energy transfer in homogeneous and heterogeneous media, photocatalysis, and photoelectrochemistry. Naturally occurring photosynthetic reaction centers and antenna systems are studied as models of biomimetic/ photocatalytic assemblies that can carry out efficient photoinduced charge separation.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
▸ Related to the photochemistry program but using different techniques is the radiation chemistry research program. This program supports research on the chemical effects produced by the absorption of energy from ionizing radiation. A major goal is to obtain molecular level information on chemical reactivity in solution, reactive transient intermediates, the kinetics and mechanisms of chemical reactions and processes at the solid/liquid interface. Frequently the studies are on systems that are not amenable to investigation by other techniques. Results from this research provide information on transients in solution and intermediates at liquid/solid interfaces for resolving important issues in solar photochemical energy conversion, environmental waste management and remediation; and intermediates relevant to nuclear energy production.			
▸ Recent workshops entitled "Research Opportunities in Photochemical Sciences" and "Research Needs and Opportunities in Radiation Chemistry" have helped identify issues for FY 2000 emphasis. These include: the fundamental mechanisms of inorganic and organic semiconductor electrode corrosion and passivation; improved theoretical models of heterogeneous electron and hole transfer across semiconductor interfaces; studies of the photophysics and chemistry of molecular excited states; control of the energetics of water splitting redox chemistry; and better understanding of the fundamental principles of photoinduced energy and charge transfer in natural and artificial photosystems as functions of structure, energetics, and medium.			
▸ Capital equipment is provided for such items as lasers, microscope scanners, liquid chromatographs, and temperature controllers.	24,907	23,927	22,982

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **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.	26,713	27,836	27,401

■ **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. 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.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Furthermore, work in AMO science has produced measurement techniques and instrumentation that is widely used by other scientific disciplines and by industry and medical sciences.			
▸ A recent workshop entitled "Atomic, Molecular, and Optical Physics Workshop" has helped define areas of priority for BES for FY 2000 and beyond. That workshop was the first in a series of annual workshops that will link the BES-supported AMO science community with other scientific and technical communities. Program priorities include a detailed understanding of the interactions of photons, electrons, ions, and heavy particles with matter including a fundamental understanding of the interaction of optical electromagnetic fields with matter in the high field regime; novel states of matter induced by such interactions; and the control of matter by these light fields. Priority research also incudes studies of novel materials such as nanostructured materials, quantum dots, and artificial atoms; and heavy-ion and highly-charged ion collisions.			
▸ Capital equipment is provided for such items as pulse processing electronics, laser upgrades, position sensitive and solid state (SiLi) detectors.	9,926	10,200	10,213

- **Catalysis and Chemical Transformations:**

  - This activity supports basic research related to chemical transformations and conversions that are fundamental to new or existing concepts of energy production and storage. The emphasis is on understanding the fundamental chemical principles underlying the 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; the conversion of biomass and related cellulosic wastes; and the

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
chemistry of precursors to advanced materials. The disciplines of organic, organometallic, inorganic, physical, and thermochemistry are central to these programs.			
▸ 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 that they replace or which function as energy-saving media themselves. These activities are linked with other catalyst related activities in BES in the materials chemistry and chemical physics programs; to other activities in the Department (Office of Heavy Vehicle Technology and the Office of Industrial Technology within EE, the Office of Fossil Energy, and the Office of International Development), and to programs at NSF.			
▸ For FY 2000, new opportunities identified through workshops and changing directions within this field of science are in aqueous catalytic chemistry, understanding the interface between water and catalytic oxides, and in catalytic activation and conversion of chlorofluorocarbons. Another area associated with the Climate Change Technology Initiative is the development of catalysts and catalytic processes for the transformation of carbon dioxide, i.e., the development of chemistry for new or improved CO_2 sequestration concepts.			
▸ Capital equipment is provided for such items as ultrahigh vacuum equipment, Fourier-transform infrared instrumentation, and high-field, solid-state NMR spectrometers.	21,883	23,401	22,854

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ Separations and Analysis:			
▸ The separations science activity supports basic research to improve our understanding of methods for separating mixtures of gases, liquids, solids, and their component molecules, cations, and anions. The program covers a broad spectrum of separations concepts, including membrane processes, extraction under both standard and supercritical conditions, adsorption, chromatography, photodissociation, and complexation. The research addresses the fundamental molecular level questions underlying the single most energy consuming of all industrial processes -- separations. The science has wide applicability and the potential for significant savings. There are strong links between this effort and the separations and analysis efforts in the Environmental Management Science Program.			
▸ The analysis activity supports research on phenomena basic to analytical methods with the goal of improving the sensitivity, reliability, and/or productivity of analytical determinations. Chemical and physical principles that can lead to entirely new methods of analysis are investigated; however, this program does not support instrument development. Rather, the program is aimed at obtaining a thorough understanding of the basic chemistry of analytical techniques so that their utility can be realized.			
▸ Several opportunities have been identified for FY 2000 that would provide the foundations needed to advance new technologies. These include advances in ceramic membranes, improved understanding of supercritical fluids for separations, applications of combinatorial chemistry to ligand design, reliable calibration methods for laser ablation sources, and improved understanding of surface-enhanced Raman spectroscopy.			
▸ Capital equipment is provided for such items as computational workstations and inductively-coupled plasma atomic emission spectrometers.	14,248	13,528	13,406

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Heavy Element Chemistry:**			
▸ This program focuses on the chemical and certain physical properties of the actinide elements, principally the transuranium elements. A variety of investigations are pursued, including organometallic chemistry, chemistry of excited spectroscopic states, thermochemistry of actinide elements and compounds, chemistry of actinides in near-neutral aqueous solutions, the reactions of aqueous actinide ions with various complexing agents, development of preparative methods for actinide metals, and compounds and characterization of actinides in the solid state under pressure. This research is performed principally at the national laboratories because of the special facilities required for handling radioactivity.			
▸ This program is the principal source of support in fundamental chemistry of the actinide elements for the Nation. The Department has assumed 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.			
▸ For FY 2000, new opportunities have been identified in the emerging areas of aqueous coordination chemistry, solid-state speciation and reactivity, and advanced theoretical methods for the prediction of electronic and molecular structure and reactivity.			
▸ Capital equipment is provided for such items as an x-ray diffractometer and equipment for a synchrotron light source end station.	6,239	6,862	6,774

	(dollars in thousands)	
FY 1998	FY 1999	FY 2000

- **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. Areas of research include anode, cathode, and electrolyte systems and their interactions with emphasis on improvements in battery size, weight, life, and recharge cycles. The 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.

  - This activity provides support for those fundamental chemical engineering sciences that underpin nearly all energy intensive industrial chemical processes; particular emphasis is placed on electrochemical storage and turbulence both in combustion and in fluid flow where significant energy savings are possible. There are strong links with the combustion efforts in chemical physics and with other combustion efforts within the Department coordinated through the Combustion Coordinating Committee. The battery research efforts are coordinated with those in the Office of Transportation Technologies and the federal interagency battery consortium.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
▸ For FY 2000 a new opportunity has been identified associated with the need to couple the current emphasis of the program in molecular simulations with molecular level theory.	8,044	8,869	8,448
■ **Climate Change Technology Initiative:** Basic research in carbon management will emphasize atomic and molecular level understanding of chemical processes to enable predictive capability. A major component of the research will aim 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 particular, multidisciplinary efforts are required that focus on improved understanding of new and existing chemical and physical separation processes, transport mechanisms, and membrane systems with selective chemical functionality; this work will address issues that are critical to clean and efficient fuels in a reduced green-house-gas economy, such as separation of CO_2 from complex mixtures or new concepts for economical oxygen separation from air for partial oxidation schemes. In addition, work will be initiated using supercritical carbon dioxide as a reagent for the catalytic and photochemical reduction of carbon dioxide to specialty chemicals or hydrocarbons, thus preventing their release into the atmosphere. 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.	0	2,197	4,394

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Scientific Simulation Initiative, Combustion Simulation and Modeling:** This research effort, part of the overall DOE Scientific Simulation Initiative, will develop, through simulation and modeling, a deep and detailed understanding of combustion processes to accelerate the development, characterization, and validation of design tools for advanced combustion devices. Combustion processes are extraordinarily complex, consisting of hundreds of chemical reactions that comprise combustion chemistry, fluid dynamics with turbulence scales covering 6 orders of magnitude, and interactions between chemistry and fluid dynamics involving time and spatial scales that cover 12 orders of magnitude. To address this complexity, the problem will be broken into computational regimes: device scale, subgrid, and chemistry models. The chemistry models, using modern quantum mechanical computational methods, will calculate the rates of component, combustion reactions that cannot be measured. The subgrid models incorporate the detailed interaction of chemistry with fluid dynamics at a scale that is independent of the combustion device and provide data on material and energy balance required by the device scale models. The device scale model completes the simulation, incorporating the results and parameters supplied by the other two regimes into a description of the overall device performance. Models for each of the three regimes can and will be developed concurrently and interactively. The fundamental physical laws that govern combustion behavior are known. Computational codes that can take advantage of parallel computer architectures are already under development for each of the three regimes. Provision of sufficient fidelity in the prediction of combustion device performance, particularly the emission characteristics of combustion devices, will require computational resources of the scale being planned for the overall Scientific Simulation Initiative. The knowledge gained will be used by the combustion engineering community to develop design and optimization codes for new combustion devices.	0	0	6,828

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **General Plant Project (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 GPP funding is included in the Facilities Operations justification. The total estimated cost of each GPP project will not exceed $5,000,000.	9,992	10,275	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.	6,500	5,655	5,655
Subtotal, Chemical Sciences Research	128,452	132,750	139,230

Facilities Operations

- **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.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Included in FY 2000 is the third and final major increment to the HFIR operating budget of $5,979,000 for the replacement of the beryllium reflector. The reflector replacement includes fabrication of the new reflector, disassembly and reassembly of the reactor and beam room, and associated safety and engineering activities. Reflector replacement, which began in FY 1998 and will be completed in FY 2000, is a recurring activity that must be performed every 10-12 years. 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.	67,675	68,928	71,430

	(dollars in thousands)		
Facilities	FY 1998	FY 1999	FY 2000
National Synchrotron Light Source	7,949	8,082	8,233
High Flux Isotope Reactor	29,798	29,659	32,974
Radiochemical Engineering Development Center	6,705	7,027	7,168
Stanford Synchrotron Radiation Laboratory	17,607	18,740	17,939
Combustion Research Facility	5,161	5,024	5,116
Partial Offset to Science General Reduction Applied to BES	455	396	0
Total, Facilities	67,675	68,928	71,430

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
SBIR/STTR Funding			
■ In FY 1998 $4,270,000 and $256,000 were transferred to the SBIR and STTR programs, respectively. In FY 1999 and FY 2000 the amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.	0	4,672	4,917
Congressional Direction			
■ Funds research related to identification of trace element isotopes in environmental samples at the University of Nevada - Las Vegas (per Congressional Direction).	0	487	0
Total, Chemical Sciences	196,127	206,837	215,577

Explanation of Funding Changes From FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Chemical Sciences Research	
■ Decrease in research for photochemistry and radiation research.	-945
■ Decrease in research for chemical physics.	-435
■ No change in atomic, molecular and optical sciences research	+13
■ Decrease in research for catalysis and chemical transformations	-547
■ Decrease in research for separations and analysis	-122
■ Decrease in research for heavy element chemistry	-88
■ Decrease in research for chemical energy and chemical engineering	-421

	FY 2000 vs. FY 1999 ($000)
■ Increase support for the Climate Change Technology Initiative.	+2,197
■ Initiate the Combustion Simulation and Modeling Research effort as part of the overall DOE Scientific Simulation Initiative.	+6,828
Total, Chemical Sciences Research	+6,480
Facilities Operations	
■ Provide increase for scientific facilities, except for the beamline at SSRL that was completed in FY 1999. Also includes support of the beryllium reflector replacement at HFIR	+2,502
SBIR/STTR	
■ Increase SBIR/STTR funding due to increase in operating expenses	+245
Congressional Direction	
■ Funding completed on Congressionally directed project..	-487
Total Funding Change, Chemical Sciences	+8,740

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 environmental remediation of polluted sites.

Climate Change Technology Initiative. The Geosciences Research Program will enhance the scientific underpinning necessary for improving the characterization of subsurface formations and their host potential for carbon dioxide sequestration. Geomechanical studies and research on rock-fluid interactions will support evaluations of carbon dioxide injection technologies, reservoir storage capacities, and long-term storage stability. Research concerning the physics of flow for multiple reactive fluid phases in fractured rock systems will provide the basis for predicting the viability of terrestrial carbon dioxide sequestration and for improved efficiency of fossil energy and geothermal energy production. Additional research in geochemistry will complement the research activities in geophysics with investigations to enhance understanding of the geochemical reactivity within the reservoirs/aquifers under static and dynamic flow conditions for fluids enriched in constituents important for CO_2 sequestration.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Engineering Research	17,296	17,471	14,500	-2,971	-17.0%
Geosciences Research	22,855	24,189	22,097	-2,092	-8.6%
SBIR/STTR	0	1,079	948	-131	-12.1%
Total, Engineering and Geosciences	40,151	42,739	37,545	-5,194	-12.2%

Detailed Program Justification

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
Engineering Research			
■ **Engineering Research:** The Engineering Research activity supports work in three technical areas: (1) mechanical systems including fluid mechanics, heat transfer, and solid mechanics; (2) systems sciences including process control, instrumentation, and intelligent machines and systems; and (3) 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 2000, funding will be terminated for research in turbulence, control systems, integrated manufacturing, and combustion. Research will be decreased in fluid dynamics and flow through porous research in bodies.	17,296	17,471	14,500
Geosciences Research			
■ **Geosciences Research:** The Geosciences Research activity supports basic research in geophysics and geochemistry to improve the level of understanding necessary for advances in and choices among current and emerging energy and environmental technologies. Geochemical research focuses on fundamental understanding of mineral-fluid interactions to provide a better foundation for oil, gas, and geothermal resource recovery and control of contaminants in groundwater flow; new fundamental thermodynamic and physical property information on rocks, minerals, and geologic fluids for resource recovery and contaminant assessment and monitoring; and extending the applicability of isotopic tracer methods for evaluation of natural and human-perturbed processes in the geologic environment. This information, in concert with other geosciences research, is providing the basis for efforts leading to quantitative predictive capabilities for processes that take place in the			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Earth's crust. In FY 2000, funding will be terminated on mechanical stability of porous reservoirs and multi-phase flow through porous bodies. Funding will be reduced in geochemistry and geophysics.	22,855	22,725	15,275
■ **Climate Change Technology Initiative:** Basic research in carbon management for the Climate Change Technology Initiative will emphasize those aspects of geosciences and engineering that will provide the understanding needed for sequestration of carbon dioxide in subsurface reservoirs. The research program will focus on three areas where improved understanding is needed to evaluate the potential for deep underground sequestration: (1) understanding the mechanical stability of porous and fractured reservoirs/aquifers during injection and over the long times required for sequestration; (2) understanding flow of fluids with multiple phases within the aquifers; and (3) understanding the geochemical reactivity within and among fluids, and between fluids and rock material within the reservoirs/aquifers. In order to understand the mechanical stability of formations, a better understanding of the stress-strain-poroelasticity- viscoelasticity-thermoelasticity constitutive relationships are necessary, as are fracture mechanics models, improved seismic models, and inversion codes to track mechanical stability of rocks at reservoir depths and scales. Fluid flow studies are need to understand mixing, fingering and phase retardation, fluid-fluid transport at ambient and injection conditions, fluid-fluid-mineral interactions including wetting behavior, and surface tension effects. In order to understand the mechanical stability of potential storage formations, a better understanding of the geochemical reactivity of reservoirs/aquifers -- under conditions involving fluids rich in constituents important for CO_2 sequestration and in the presence of interacting mineral-fluid system -- will be needed to fully evaluate these systems in terms of sequestration potential and safety..	0	1,464	6,822
Total, Geosciences Research	22,855	24,189	22,097

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
SBIR/STTR Funding			
■ In FY 1998 $984,000 and $59,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.	0	1,079	948
Total, Engineering and Geosciences	40,151	42,739	37,545

Explanation of Funding Changes From FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Engineering Research	
■ Termination of engineering research on turbulence, control systems, integrated manufacturing, and combustion and decrease in research on fluid dynamics. . . .	-2,971
Geosciences Research	
■ Termination of geosciences research on mechanical stability of porous reservoirs and multi-phase flow through porous bodies and decrease in geochemistry and geophysics to provide increase in Climate Change Technology Initiative and other priority areas..	-7,450
■ Increase in Climate Change Technology Initiative.	+5,358
Total, Geosciences Research	-2,092
SBIR/STTR	
■ Decrease SBIR/STTR funding due to increase in operating expenses.	-131
Total Funding Change, Engineering and Geosciences	-5,194

Energy Biosciences

Mission Supporting Goals and Objectives

The Energy Biosciences subprogram supports mechanistic research on fundamental biological processes related to capture, transformation, storage and utilization of energy. The research focuses on plants and non-medical microorganisms to form a broad scientific foundation for support of Department of Energy's goals and objectives in energy production, environmental management, and energy conservation. Basic research on plants includes photosynthetic mechanisms and bioenergetics in algae, higher plants, and photosynthetic bacteria; control mechanisms that regulate plant growth and development; fundamental aspects of gene structure, function, and expression; plant cell wall structure, function and synthesis; and mechanisms of transport across membranes. Research supported in these areas seeks to define and understand the biological mechanisms that effectively transduce light energy into chemical energy, to identify the biochemical pathways and genetic regulatory mechanisms that can lead the efficient biosynthesis of potential fuels and petroleum-replacing compounds, and to elucidate the capacity of plants to remediate contaminated environments by transporting and detoxifying toxic substances. The research focus in the microbiological sciences includes the degradation of biopolymers such as lignin and cellulose, anaerobic fermentations, genetic regulation of microbial growth and development, thermophily, e.g., bacterial growth under high temperature, and other phenomena with the potential to impact biological energy production, conversion and conservation. Organisms and processes that offer unique possibilities for research at the interface of biology and the physical, earth and engineering sciences are also studied.

Climate Change Technology Initiative. Biological systems, particularly plants, algae, and microbes, play a major role in the capture and release of atmospheric carbon dioxide. Photosynthetic organisms use sunlight to convert carbon dioxide into more complex organic compounds, while many non-photosynthetic organisms use the energy in various inorganic and organic compounds to fix 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.

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Energy Biosciences	26,710	29,088	30,410	+1,322	+4.5%
SBIR/STTR	0	774	816	+42	+5.4%
Total, Energy Biosciences	26,710	29,862	31,226	+1,364	+4.6%

Detailed Program Justification

(dollars in thousands)		
FY 1998	FY 1999	FY 2000

Energy Biosciences

- **Energy Biosciences**: This activity supports basic research in the energy-related biosciences forming the mechanistic foundation for the development of future biotechnologies related to energy. This work provides the knowledge necessary to use biological systems associated with the capture, transformation, storage and utilization of energy, and other significant missions of the Department of Energy. Those programs within the Department that are active in creating or exploiting technologies are supported through numerous interactions at both the manager and the researcher level. The Basic Energy Sciences program is scientifically heterogeneous and many efforts are made to encourage the development of truly interdisciplinary research activities. The Energy Biosciences subprogram is actively involved with other federal agencies funding basic plant and microbial research to encourage effective and efficient management of the total federal research portfolio.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
The successes of this subprogram, along with other federal research efforts, are developing an expanding science knowledge base leading to the rapid expansion of biotechnological applications using both plants and microbes. The formation of numerous large "life science" corporations is indicative of this trend. Ongoing basic research is leading to numerous new and unexploited research opportunities, including functional plant genomics, organellar and chromosome-level bioengineering, elucidation of new biochemistries, and determiantion of cellular and morphological development. Each of these areas have the potential to be commercially applied, resulting in major economic and societal impacts ranging from the revitalization of the rural economy through dispersal of the nation's manufacturing base to the formation of a new generation of bio-based industries; in addition to having a major impact on the nation's production and use of energy expensive chemicals and fuels. Recently, private and charitable research foundations have responded to both the opportunities and impacts of fundamental research in these areas and are building large basic research institutes in St. Louis and San Diego. They have the resources to build the needed facilities, but are relying on the federal government to provide the long-term support of the research activities and to provide the required scientific personnel. Capital Equipment is provided for items used for structure determination and for special analysis of biomaterials. .	26,710	26,652	25,537

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Climate Change Technology Initiative:** Basic research in carbon management for the Climate Change Technology Initiative begun in FY 1999 emphasized the biological process of photosynthesis, which is central to global carbon cycling. The primary current focus of these photosynthesis activities is the biophysics and biochemistry of energy capture and structural studies on the photosynthetic apparatus. There are a number of unexplored opportunities that complement this work with studies on the mechanism of photosynthetic carbon fixation and the subsequent metabolism of the fixed carbon. An example of the research supported are studies to provide a fundamental understanding of chloroplasts, which are small membrane bound entities in the cytoplasm of plant cells where photosynthesis occurs. Chloroplasts contain DNA and are able to control their development and replication. The new research will investigate the principals underlying the biochemical and molecular genetic mechanisms of chloroplast development and reproduction along with critical interactions of chloroplasts with the cytoplasm and nucleus. The understanding obtained from these 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.	0	2,436	4,873
Total, Energy Biosciences	26,710	29,088	30,410
SBIR/STTR Funding			
■ In FY 1998 $672,000 and $40,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts shown are the estimated requirement for the continuation of the SBIR/STTR programs.	0	774	816
Total, Energy Biosciences	26,710	29,862	31,226

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Energy Biosciences	
■ Decrease in support of research providing the fundamental understanding of life processes in plant and microbes.	-1,115
■ Increase in support for Climate Change Technology Initiative.	+2,437
Total, Energy Biosciences	+1,322
SBIR/STTR	
■ Increase in SBIR/STTR funding due to increase in operating expenses.	+42
Total Funding Change, Energy Biosciences	+1,364

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.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Construction	7,000	105,400	196,100	+90,700	+86.0%
Total, Construction	7,000	105,400	196,100	+90,700	+86.0%

Detailed Program Justification

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
Construction			
■ Funding for the Combustion Research Facility, Phase II was completed in FY 1999 as scheduled.	7,000	4,000	0
■ The FY 2000 requested budget authority will provide for: continuation of Title I design, the start of Title II design activities, initiation of construction of conventional facilities, procurement of several significant technical components, and continued research and development activities for the Spallation Neutron Source.	0	101,400	196,100
Total, Construction	7,000	105,400	196,100

Explanation of Funding Changes From FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Construction	
■ The decrease in funding for the construction of the Combustion Research Facility, Phase II project is a result of the scheduled completion of this project .	-4,000
■ The increase in funding for the Spallation Neutron Source represents the scheduled ramp up of activities.	+94,700
Total Funding Change, Construction	+90,700

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 operation of these facilities is provided in the Materials Sciences and Chemical Sciences subprograms.

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
National Synchrotron Light Source	30,996	32,176	32,756	+580	+1.8%
High Flux Beam Reactor	22,986	22,568	22,580	+12	-+0.1%
Intense Pulsed Neutron Source	11,230	11,982	11,985	+3	0.0%
High Flux Isotope Reactor	33,770	29,659	34,574	+4,915	+16.6%
Radiochemical Engineering Development Center	6,705	7,027	7,168	+141	+2.0%
Stanford Synchrotron Radiation Laboratory	21,684	22,686	21,968	-718	-3.2%
Manuel Lujan, Jr. Neutron Scattering Center	6,588	7,397	7,547	+150	+2.0%
Combustion Research Facility	5,161	5,024	5,116	+92	+1.8%
Advanced Light Source	30,708	31,166	31,732	+566	+1.8%
Advanced Photon Source	82,368	86,226	87,703	+1,477	+1.7%
Spallation Neutron Source	0	28,600	17,900	-10,700	-37.4%
Partial Offset to Science General Reduction Applied to BES	1,555	1,521	0	-1,521	-100.0%
Total, Major User Facilities	253,751	286,032	281,029	-5,003	-1.7%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Facilities Operations			
■ National Synchrotron Light Source at Brookhaven National Laboratory.	30,996	32,176	32,756

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ High Flux Beam Reactor at Brookhaven National Laboratory. On December 21, 1996, the High Flux Beam Reactor (HFBR) was shut down for normal refueling. However, before the reactor was restarted, the announcement was made that a plume of tritium, believed to emanate from the reactor spent fuel pool, was contaminating the ground water south of the reactor. The reactor has remained in standby mode since that time. Because the reactor contains radioactive fluids in the primary cooling system, nearly a full staff is necessary to maintain the reactor and associated equipment in safe operating condition. The funding requested in FY 2000 represents that required to maintain the reactor and to proceed with safety modifications that are required regardless of whether the reactor is restarted or is decommissioned.	22,986	22,568	22,580
■ Intense Pulsed Neutron Source at Argonne National Laboratory.	11,230	11,982	11,985
■ High Flux Isotope Reactor at Oak Ridge National Laboratory. There will be a continuation of increased operating support in FY 2000 to take advantage of the new cold source with 3 new experimental stations and to support the scheduled replacement of the beryllium reflector. Also, includes AIP funding of $3,972,000 in FY 1998 for HB-2 tube upgrades and $1,600,000 in FY 2000 for HB-4 Beamline Enclosure.	33,770	29,659	34,574
■ Radiochemical Engineering Development Center at Oak Ridge National Laboratory.	6,705	7,027	7,168
■ Stanford Synchrotron Radiation Laboratory at Stanford University. The decrease is the result of scheduled completion of Beamline 11.	21,684	22,686	21,968
■ Manuel Lujan, Jr. Neutron Scattering Center at Los Alamos National Laboratory.	6,588	7,397	7,547
■ Combustion Research Facility at Sandia National Laboratories/California.	5,161	5,024	5,116

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ Advanced Light Source at Lawrence Berkeley National Laboratory.	30,708	31,166	31,732
■ Advanced Photon Source at Argonne National Laboratory.	82,368	86,226	87,703
■ Spallation Neuron Source.	0	28,600	17,900
■ Partial Offset to ESRD General Reduction Applied to BES.	1,555	1,521	0
Total, Major User Facilities	253,751	286,032	281,029

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
General Plant Projects	10,342	10,625	10,625	0	0.0%
Accelerator Improvement Projects . .	11,502	7,108	8,195	+1,087	+15.3%
Capital Equipment	49,809	57,114	55,178	-1,936	-3.4%
Total, Capital Operating Expenses . . .	71,653	74,847	73,998	-849	-1.1%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1998	FY 1999	FY 2000	Unapprop-riated Balance
99-E-334 Spallation Neutron Source, ORNL	1,159,500	0	0	101,400	196,100	862,000
96-E-300 Combustion Research Facility, Phase II, SNL	26,800	15,800	7,000	4,000	0	0
Total, Construction		15,800	7,000	105,400	196,100	862,000

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1998	FY 1999	FY 2000	Accept-ance Date
Short Pulse Spallation Upgrade at LANSCE - LANL	20,500	0	4,500	4,500	6,000	FY 2001
HB-2 Beam Tube Extension at HFIR - ORNL	5,900	0	0	3,500	2,400	FY 2000
Total, Major Items of Equipment . .		0	4,500	8,000	8,400	

99-E-334 — Spallation Neutron Source, Oak Ridge National Laboratory, Oak Ridge, Tennessee

(Changes from FY 1999 Congressional Budget Request are denoted with a vertical line in the left margin.)

Significant Changes

The Total Estimated Cost and Total Project Cost have been increased and the construction schedule has been extended. The schedule delay and increased costs are a result of the planned FY 1999 funding being reduced by $27,000,000 in the FY 1999 appropriation.

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 (*Current Estimate*)	1Q 1999	4Q 2003	3Q 2000	1 Q 2006	1,159,500	1,360,000

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Construction			
1999	101,400	101,400	53,700
2000	196,100	196,100	166,200
2001	267,900	267,900	263,800
2002	262,500	262,500	274,100
2003	193,600	193,600	207,300
2004	78,300	78,300	131,700
2005	49,200	49,200	47,200
2006	10,500	10,500	15,500

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 next century.

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.

Neutron probes 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 1996 Russell Panel Report, the SNS has been designed to operate at an average power on target of about 1 MW. At this power level, the SNS will be the most powerful spallation source in the world--six times that of ISIS at the Rutherford Appleton Laboratory in the United Kingdom. However, the SNS has been deliberately designed to allow for economical upgrading to substantially higher powers once the technology is developed to make this possible. 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 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 they have spin, neutrons have a magnetic moment and can be used to study magnetic structure and magnetic properties of materials. Because their interactions are known with great accuracy, neutron scattering is far more easily interpreted than either photon scattering or electron scattering.

However, the same properties that make neutrons an ideal probe of matter also result in their most significant disadvantage. Because neutrons interact only weakly with matter, most neutrons pass through a sample without producing a detectable interaction. Therefore, neutron scattering experiments are said to be extremely "flux limited." This situation is further exacerbated because, unlike photons and charged particles, neutrons cannot be focused. Therefore, high brilliance (i.e., highly focused) neutron beams are very difficult to make. The combination of weak interaction and inherent low brilliance has driven the quest for high-flux neutron sources. 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 next century and to address the mix of needs associated with the user community, the operations staff, security, contamination control, noise, etc.

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 1999 budget authority allowed the start of Title I design activities, initiation of subcontracts and long-lead procurements, and continuation of critical research and development work necessary to reduce technical and schedule risks in this project. Initiation of most long-lead procurements is delayed until FY 2000 due to the reduction in the FY 1999 appropriation.

FY 2000 funding of $214,000,000 is requested for the SNS Project for detailed design (Title II) for the ion source, low-energy beam transport, linac structure and magnet systems, target assemblies, experimental instruments, and global control systems. Detailed design will be completed for several conventional facilities in preparation for the installation of major equipment in the following fiscal year; design will be completed 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 start for some conventional facilities including roads into the site, site preparation/grading, waste systems, and retention basins. Procurement for several significant equipment items such as dipole magnets, material for the target transport systems, and klystrons will begin. Project Management and Project Integration activities, which are exceptionally important during this phase of the project, will also be conducted. The Preliminary Safety Analysis Report (PSAR) will be completed during the fiscal year and work will begin on the final report.

4. Details of Cost Estimate [a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design and Management Costs		
Engineering, design and inspection at approximately 26% of construction costs	166,900	166,900
Construction management at approximately 4% of construction costs	26,300	26,300
Project management at approximately 15% of construction costs	102,900	96,800
Land and land rights	0	0
Construction Costs		
Improvements to land (grading, paving, landscaping, and sidewalks)	28,600	28,600
Buildings	176,700	176,700
Other structures	600	600
Utilities (electrical, water, steam, and sewer lines)	30,500	30,500
Technical Components	417,900	406,300
Standard Equipment	1,100	1,100
Major computer items	12,000	12,000
Removal cost less salvage	0	0
Design and project liason, testing, checkout and acceptance	9,700	6,700
Subtotal	973,200	952,500
Contingencies at approximately 19 percent of above costs	186,300	186,300
Total Line Item Cost	1,159,500	1,138,800
Less: Non-Agency Contribution	0	0
Total, Line Item Costs (TEC)	1,159,500	1,138,800

5. Method of Performance

The ORNL Management and Operating Contractor will provide overall project management and integration, design and ultimate procurement of the target station, beam transport, and experiment systems, and will subcontract for the services of an Industry Team for design and construction management services. The Industry Team will consist of an Architect-Engineer for the conventional facilities design and a Construction Manager for construction, installation, equipment procurement, testing and preoperational support. Other DOE laboratories will, through intra laboratory agreements, become members of the overall project's management, design and R&D team, particularly in the areas encompassed by the linac, the accumulator ring, instrumentation, and the target. Procurement and

a The cost estimate is based on a conceptual design completed in FY 1997. The DOE Headquarters Economic Escalation indices were used as appropriate over the project cycle.

construction will be accomplished, to the extent feasible, by fixed-priced subcontracts awarded to industry on the basis of competitive bidding.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 1998	FY 1999	FY 2000	Outyears	Total
Project Cost						
Facility Cost [a]						
Line Item TEC	0	0	53,700	166,200	939,600	1,159,500
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	0	53,700	166,200	939,600	1,159,500
Other project costs						
R&D necessary to complete project [b]	200	21,400	25,300	16,300	26,200	89,400
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]	0	1,500	400	0	0	1,900
Other project-related costs [e]	0	0	800	900	89,097	90,797
Capital equipment not related construction [f]	0	100	2,100	700	200	3,100
Total, Other project costs	15,503	23,000	28,600	17,900	115,497	200,500
Total project cost (TPC)	15,503	23,000	82,300	184,100	1,055,097	1,360,000

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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 $1,159,500,000.

b A research and development program at an estimated cost of $89,400,000 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 $90,797,000 are included to cover pre-operations costs.

f Estimated costs of $3,100,000 to provide test facilities and other capital equipment to support the R&D program.

7. Related Annual Funding Requirements [a]

	(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

[a] Expressed in FY 2006 dollars, the first full year of operation.

Computational and Technology Research

Program Mission

The mission of the Computational and Technology Research (CTR) program, which consists of two distinct activities, is

- to foster and support fundamental research in advanced computing research — applied mathematics, computer science, and networking — and to operate supercomputer, networking, and related facilities to enable the analysis, modeling, simulation, and prediction of complex phenomena important to the Department of Energy, and
- 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 this program is continuously evaluated through the use of merit based peer review and scientific advisory committees.

Program Goals

- Maintain world leadership in areas of advanced computing research relevant to the complex problems of the Department of Energy.
- Integrate the results of advanced computing research into the natural sciences and engineering.
- Provide world-class supercomputer and networking facilities for scientists working on problems that are important for the Department.
- Integrate and disseminate the results of high-risk research in the natural sciences and engineering to the private sector through the Laboratory Technology Research subprogram.

Program Objectives

- *Foster and support fundamental, peer-reviewed research.* — Foster research to create new fundamental knowledge in areas of advanced computing research important to the Department.
- *Apply advanced computing knowledge to complex problems of importance to DOE.* — Promote the transfer of the results of advanced computing research to contribute 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.
- *Plan, fabricate, assemble, 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 Computational and Technology Research program measures performance in various ways, depending on the objective. However, performance measures fall into four broad categories: (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. The key process is peer review of all research activities. 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, CTR supercomputer and network facilities have periodic external performance reviews. The Energy Science Network (ESnet) operations and management were reviewed in this manner in FY 1998.

In FY 2000, (1) facilities, including the National Energy Research Scientific Computing Center (NERSC) and ESnet, will be operated within budget to meet user and overall SC program requirements; (2) 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; (3) all new and continuing research projects will undergo regular peer review and merit evaluation based on the principles set down in 10 CFR 605 for grants or in cooperative agreements supported by the Office of Science; (4) work performed by investigators supported by CTR will continue to be recognized as outstanding through the receipt of major prizes and awards; and (5) initiate 7 Laboratory Technology Research projects that address the Department's top priorities for science and technology, through cost-shared research partnerships with industry.

Significant Accomplishments and Program Shifts

The CTR program builds on decades of leadership in advanced computing. Some of the pioneering accomplishments of this program are:

Mathematical, Information, and Computational Sciences

- **Remote, interactive access to supercomputers**. At the National Magnetic Fusion Energy Computing Center [the predecessor to the National Energy Research Scientific Computing Center (NERSC)], DOE 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 see 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.

- **Numerical Linear Algebra Libraries**. Today's high performance 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 and 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.

- **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. Many research issues in high speed signaling, data parallelism and high speed protocol design needed to be understood to enable this advance.

- **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.

- **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 6 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 Computational and Technology Research program this year received recognition through numerous prizes, awards, and honors. A sample of the significant accomplishments produced by the program this year is given below.

- **1998 Gordon Bell Prize for Best Performance of a Supercomputing Application.** An international team of scientists including those from the Department's Oak Ridge and Lawrence Berkeley National Laboratories won the 1998 Gordon Bell prize for best performance of a supercomputing application for simulation of magnetism metal alloys. The team won the award for their modeling of 1,024 atoms of a metallic magnet. The calculation submitted by the team to the Gordon Bell Prize judges performed at 657 Gigaflops performance level (657 billion calculations per second); however, the team subsequently was able to raise the performance of their application to more than one teraflop (one trillion calculations per second.) In addition to supporting the winning entry, the CTR program partially supported the two other finalists.

- **1998 Fernbach Award**. Dr. Phillip Colella, a mathematician at DOE's Lawrence Berkeley National Laboratory, received the 1998 Sidney Fernbach Award at the SC98 conference in Orlando. Colella received the award for his "outstanding contribution in the application of high performance computers using innovative approaches." The Fernbach Award, created in memory of a computer scientist at DOE's Lawrence Livermore National Laboratory, is presented by the IEEE (Institute of Electrical and Electronics Engineers) Computer Society. Dr. Colella's research has focused on problems in Computational Fluid Dynamics and advanced techniques for the generation of the grids that form the basis for many scientific computations. His research has been applied to problems in the simulation of combustion devices as well as national security applications.

- **Simulation of Instabilities in Fluid Layers**. Many important physical systems can be described as layered fluids. For example, layers of oil float on salt water in geological structures. Even structures with layers of metal behave like layered fluids under high pressure and temperature. These types of systems develop very complex, unstable structures at the boundary between fluids. Computation of the characteristics of these boundaries is especially difficult, because their locations must be tracked accurately as part of the calculation. In addition, the most common formulations of the problem require many more grid points than are practical on even the largest computers. Applied mathematicians at the State University of New York, Stony Brook, in collaboration with physicists at Los Alamos National Laboratory (LANL) have discovered and implemented clever numerical schemes capable of following surfaces that can evolve into complicated shapes over time. They have used these new techniques to simulate this type of fluid instability under conditions where experiments are not possible, thus allowing design of devices for Defense Program's Advanced Strategic Computing Initiative and fusion energy applications. Modeling and simulation are absolutely vital since experimental data will never be available for conditions of importance to the designers.

- **Research in Optimization Impacts U.S. Industry**. Applied mathematicians at Rice University, working with engineers at Boeing, developed a software package for improving the manufacture of airplane components. The software combines new approaches to the optimization of systems having hundreds of thousands of parameters with research in the theory of control systems to enable engineers to optimize manufacturing processes. Previous design schemes for Boeing's production processes were based on simple "rules of thumb" that failed often in practice, and standard optimization packages were easily overwhelmed by the sheer size of the problems. This necessitated a complete rethinking of design and optimization strategies in order to accommodate industrial-size problems. The Rice researchers developed novel techniques in nonlinear optimization theory to correctly identify the underlying problems and provide feasible solutions. Boeing is using the software on its production line to lower costs and improve quality.

- **Law for Turbulent Stress Proved to be Invalid.** To design systems such as gas turbines, airplanes, or combustion devices where flow of gasses over physical structures is important, it is critical to be able to accurately describe the turbulent stress generated by the flow of the gas over the structure. Since the turn of the century, the standard methodology for calculating this was a simple mathematical model called the "law of the wall." This model, which is found in every engineering textbook, is based on relatively crude approximations that have been accepted without serious thought since the turn of the century. Mathematicians at Lawrence Berkeley National Laboratory (LBNL) have recently developed a rigorous mathematical basis for calculating turbulent wall effects and demonstrated that the "law of the wall" is not valid in general. They showed by careful mathematical analysis that the correct description of turbulent effects on solid objects requires a family of "scaling laws" rather than a single "law of the wall." This is difficult research since it must blend hard mathematical analysis with the proper physical insights from the fluid dynamics of turbulent flows. The discovery will have profound consequences in the engineering and design of airplanes, gas turbines, and other systems where controlling turbulence is critical to performance. The mathematical predictions of the Berkeley group have been verified recently by experiments at Princeton.

- **R&D 100 Award to Sandia Researchers.** Researchers at Sandia National Laboratories were awarded an R&D 100 award in FY 1998 for the Aztec software package. Aztec is a collection of very high performance software routines that run on the highest performance computers in the nation to solve important linear algebra problems such as solving systems of millions of linear equations. This type of linear algebra is at the core solving ordinary and partial differential equations on computers as well as many other types of scientific computations. Aztec grew out of the successful research programs at Sandia in numerical linear algebra and parallel programming techniques.

- **Advanced Computing Software Tools Enable Rapid Application Development.** One of the major challenges in modern high performance computing is to develop tools that enable scientists to quickly create computer software to solve scientific problems. Otherwise, chemists, materials scientists, and others would spend their entire effort creating software for computers that would be obsolete just as the applications were ready. The speed of change in the underlying computer architectures and the complexity of these computers and their operating systems makes this a major area of research. The Parallel Object-Oriented Methods and Applications (POOMA) Framework effort at LANL is one promising research approach to developing effective tools to help scientists in the disciplines develop software. In an early test with POOMA, a post-doc with no parallel programming experience developed computer software to solve a three dimensional fluid turbulence problem (including the tools to visualize the results while the program was running) in only six weeks rather than the 6-9 months required in similar efforts. POOMA is used extensively by two of the scientific applications pilots — the computational accelerator physics and numerical tokamak turbulence projects.

- **New Scientific Application Enabled By Interfacing Two Software Packages.** One research challenge facing advanced computing is to enable software developed by different teams to work together on massively parallel computers. Recently researchers at Argonne National Laboratory (ANL) and Lawrence Livermore National Laboratory (LLNL) have demonstrated that it is possible for well-designed components developed at different laboratories to be easily used together by providing each with a common interface. The latest generation of ordinary differential equation solvers for systems, whose behavior combines fine scale and large scale features, developed at LLNL has been interfaced with a large family of parallel algebraic solvers developed at ANL. This coupled software system has enabled several new applications. One of these is a collaboration of researchers at Louisiana Tech University and Oak Ridge National Laboratory

(ORNL) to develop a code for fully three-dimensional simulations of the dynamics of micro-structural interactions in materials. This code would not have been possible before the researchers had access to the coupled ANL-LLNL system.

- **Significant Speedups Achieved For Laue Crystallographic Analysis.** Advances in numerics coupled with work to enable software to run in parallel on many processors has enabled researchers in the "Supercomputer Solution of Massive Crystallographic and Microtomographic Structural Problems" scientific application pilot project to dramatically reduce the time required to analyze the data from Laue diffraction experiments. A typical illustration comes from progress made on a scientific applications project—diffraction patterns and intensities produced by x-rays passing through a crystal lattice are used to deduce information about molecular structures. The Laue diffraction technique is the most important tool in time-resolved crystallography, where structure data are captured rapidly to image the structure of a molecule at various stages of a reaction. Improved optimization and numerical techniques have been applied to the code that performs the complicated task of analyzing Laue diffraction data to obtain the structure of the molecules. The dramatic improvements in time-to-solution that have been made will significantly enhance experimental capabilities because runtimes are reduced from hours to minutes. These results are expected to be especially important for the 30 percent of users of DOE light sources who are involved in discovering protein structures.

- **ESnet Demonstrates Priority Service For Internet Traffic.** Scientists at two national laboratories successfully selected marked Internet traffic for priority service over unmarked traffic in a cross-country demonstration. This demonstration is a key milestone in the development of a broad set of capabilities called "differentiated services," which are required for the Internet to be able to give different levels of service on demand to network customers. The demonstration of such capabilities for production-mode scientific research between Lawrence Berkeley National Laboratory and Argonne National Laboratory across the ESnet paves the way for more reliable and constant connectivity via priority bandwidth on the Internet. Achieving this improved level of service is essential to the work of the Department, which is pioneering the use of various technologies to allow scientists at more than 30 DOE national labs to share access to some of the Nation's most advanced research facilities. The complex interactions between software on computers, network hardware such as routers, and telecommunications equipment operated by commercial carriers make this a difficult research problem. In addition, all of these components must be capable of efficiently scaling up to operate across the worldwide Internet which processes tens of billions of packets a month.

- **Collaboratory Tool Attracts Users.** The electronic notebook collaboratory tool project has been so well received that over eighty groups across the country have adopted the prototype electronic notebook. Some are DOE projects, but many are from outside the Department including pharmaceuticals, chemical processing and medicine. The electronic notebook is valuable to researchers because: it can be shared by a group of researchers; it can be accessed remotely; it cannot be misplaced, lost, or accidentally destroyed (if backed up); it is easy to incorporate computer files, plots, etc.; notarization and authentication are possible; it can easily be searched for information; it can include multimedia; and it can include hyperlinks to other information. In order to enable these capabilities, the electronic notebook project has had to overcome a number of challenges including the development of new technologies for describing types of data such as experimental protocols and experimental devices, which are not well treated by traditional techniques.

Laboratory Technology Research

- In FY 1999, the SC single-purpose laboratories (Fermi National Accelerator Laboratory, Thomas Jefferson National Accelerator Facility, Princeton Plasma Physics Laboratory, and Stanford Linear Accelerator Center) and Ames Laboratory were reinstated into the Laboratory Technology Research (LTR) subprogram, thus restoring the subprogram to its original participants. LTR now provides coverage to more regions of the country where small businesses, in particular, can take advantage of the resources at SC laboratories. LTR capabilities have been enhanced for cost-shared partnerships in fusion energy sciences, high energy physics, nuclear physics, materials sciences, chemical sciences, structural biology, and other disciplines.

- The LTR subprogram received two R&D-100 awards in 1997 and three R&D-100 awards in 1998. The 1998 awards were given to:

  - Oak Ridge National Laboratory, in collaboration with the Society of Exploration Geophysicists, for “Advanced Computational Tools for 3-D Seismic Analysis.” This research was cosponsored by DOE’s Office of Fossil Energy.

  - Argonne National Laboratory in collaboration with Front Edge Technology of Baldwin Park, CA, Stirling Motors of Ann Arbor, MI, and Diesel Technology of Wyoming, MI, for “Near-Frictionless Carbon Coatings.”

  - Argonne National Laboratory, in collaboration with Commonwealth Edison of Chicago, IL, for “Combined Expert System/Neural Network for Process Fault Diagnostics.”

Advanced Energy Projects

- The Advanced Energy Projects subprogram will be terminated in FY 2000.

Scientific Facilities Utilization

The CTR program request includes $27,500,000 in FY 2000 to support the NERSC Center. This investment will provide research time for about 3,500 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.

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 $46,000 and $47,000 for estimated contractor security clearances in FY 1999 and FY 2000, respectively, within this decision unit.

Scientific Simulation Initiative

The CTR program also leads DOE's Scientific Simulation Initiative (SSI), an integrated effort bringing together computational and communication resources, focused research in scientific disciplines, and research in computer science and other enabling technologies to solve the complex problems that characterize DOE's scientific research needs. The SSI is a significant component of the broader President's Information Technology Research Initiative (ITRI) which responds to the recommendations of the President's Information Technology Advisory Committee (PITAC). The SSI couples research in advanced scientific applications in the programs of the Office of Science (SC) with research in computer science and enabling technologies and advanced computing and communications facilities. It is a joint program between CTR and the other program offices in SC. The overview of the integrated program is given here; however, the specific contributions of the other programs (Basic Energy Sciences and Biological and Environmental Research) are included in their budgets. This initiative will build on and benefit from the demonstrated capabilities brought about by the Department's Accelerated Strategic Computing Initiative (ASCI) that have made it possible to obtain computational capabilities 100 times faster than currently in common use. The mission of this proposed effort is to develop further and to employ the emerging generation of very high performance computers as major tools for scientific enquiry. These resources will revolutionize our approach to solving complex problems in energy, environment, fundamental research, and technology development as well as stimulate our national system of innovation. The goal of the SSI is to:

> *"Revolutionize our ability to solve scientific problems of extraordinary complexity and to apply these resources to scientific problems relevant to the Department's mission through the exploitation of the emerging power of exceptional computational capabilities."*

As has been discussed earlier in this budget, scientific research has long been characterized as the interplay of theory and experimentation. Over the last half century the emergence of computers for solving complex mathematical problems and for analyzing large sets of data has introduced a third activity to complement both theory and experimentation. Defined as simulation and modeling, but also encompassing a broad range of data analyses, the application of computational resources to complex scientific problems has made increasingly important contributions to scientific discovery and understanding as those resources have grown more powerful. The SSI builds on DOE's 50 year history of transforming advances in information technology into tools for scientific discovery to accelerate this process through a partnership with DOE laboratories, the academic community and industry.

This program began with workshops focused on the scientific opportunities that could result from access to multi-teraflop computing. All of the programs in the Office of Science made convincing cases that access to computing at this level would open new areas of research and enable solutions to new classes of problems. These workshops culminated in a workshop on advanced scientific and engineering computing jointly sponsored by DOE and the National Science Foundation at the National Academy of Sciences in July, 1998. This workshop validated the opportunity for scientific discovery and advanced engineering afforded by terascale computing. Throughout this document, the term teraflop is used in discussing the computational resources under consideration. One teraflop is one trillion (10^{12}) floating point operations per second. For comparison, desktop personal computers are generally capable of one hundred thousand (10^{5}) floating point operations per second. Current commercially available supercomputers are capable of nearly half teraflop performance.

Based on the input from these workshops, a plan for the SSI was developed to realize the goals of the SSI. It is a balanced plan of research which includes advanced computing and communications facilities, such as terascale computers and very high performance networks, computer science and enabling technology research to make these facilities useful, and investments in scientific disciplines to enable development of the advanced applications that will be required. The strategy for SSI applications has two components. The first was a selection of two mission critical application areas: global systems and combustion systems. In both of these cases, the initial SSI planning workshops identified significant opportunities for advanced computation to dramatically advance the state of the art with important impact on the nation's ability to respond effectively to issues such as the effect of greenhouse gasses on global climate and development of internal combustion engines able to meet societal goals for efficiency and pollution control. These two initial applications play a significant role in defining the requirements for computer and communications facilities as well as the computer science and enabling technology which will be required. These two applications will also play an important role in testing, integrating, and debugging both hardware and software components. The second component of the SSI applications strategy is an open, peer reviewed competition among basic science disciplines to select a small number for initial inclusion in the initiative and access to SSI computer and communications facilities.

The Scientific Simulation Initiative Builds on ASCI

One reason the Department is prepared to undertake this initiative at this time is that the proposed effort builds upon the DOE Defense Program (DP) Accelerated Strategic Computing Initiative (ASCI) which was launched in 1996 with a focus on multi-teraflop scale computing to meet the imposing challenges posed by Science Based Stockpile Stewardship.

Meeting the goals set for ASCI requires computers with capabilities exceeding those available today by a factor of one thousand and the ASCI program is following an aggressive hardware and software technology plan that will achieve the development and use of 100 teraflop computers by 2004. As a result of the ASCI effort, much more powerful computer systems, designed for full simulation of all scientific aspects of nuclear stockpile stewardship, have been developed. ASCI continues to develop the computational infrastructure needed to make effective use of these systems, including large-scale scientific data storage capabilities, computational grids for high-speed communication, software development systems for massively parallel computer systems, high-performance visualization systems, etc. These advances, although focused on DOE's stockpile stewardship responsibility, presage the development of a comprehensive simulation capability for a whole range of scientific problems.

A Critical Element in the President’s Initiative in Information Technology

Although the SSI is focused on revolutionary uses of computing as a tool for science, many of the investments in computer science and enabling technology will contribute to and benefit from the broader ITRI initiative. 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.

The SSI Computer Science and Enabling Technology (CSET) program has four components: Algorithms, Models, Methods and Libraries; Problem Solving Environments and Tools; Distributed Computing and Collaboration Technology; and Visualization and Data Management. The underlying strategy in all of these areas is based on taking advantage of the most recent work in software components and extending it to enable it to function at very high performance. In addition, the realities of the hardware platforms that will be available at SSI performance levels requires that the components be fault tolerant and that techniques be developed to enable the assembly of components into reliable fault tolerant assemblies. Thus, with respect to the PITAC recommendation on Software development, we expect SSI to be a significant program for fundamental research in software development methods and component technologies and to begin the development of a national repository of software components.

In addition, challenges facing SSI in the area of data management and visualization will require significant new research in the areas of human computer interfaces and interaction to enable researchers to navigate and extract scientific knowledge from petabyte-scale data archives resulting from SSI scale simulations and the coming generation of large experimental facilities. Both the SSI planning workshops as well as the ASCI Visualization Corridors workshops identified this as a critical area that would perhaps be an “Expedition to the 21st Century.”

However, there are areas of software research included in the PITAC report that SSI will not cover, particularly software for systems such as air traffic control.

With regard to the PITAC recommendation on a Scalable Information Infrastructure, SSI will have a more modest impact because the problem for The SSI is primarily providing very high performance access for a modest number of people rather than providing access to billions of users worldwide.

With regard to the PITAC recommendation on High End Computing, SSI will have a major impact on R&D to improve the performance of high end computers, acquiring high end systems to support scientific research and moving towards petaop (1000 teraflop) systems by 2010. However, while SSI is a part of the solution to the problem of access to high end computing for science and engineering research and will develop many of the technologies needed to make this possible, the computing systems proposed are scaled to support a modest number of focused scientific projects, which will be collaborative efforts of large teams of disciplinary scientists, computer and computational scientists and mathematicians.

With regard to the PITAC recommendation on Socio-Economic and Workforce Impacts, The SSI will increase research funding in relevant areas of IT and will develop strategies to retrain existing scientists and IT workers as well as train new undergraduate and graduate students in these disciplines.

In addition to the research contributions that SSI will make to the broader ITRI, SSI facilities will provide crucial testbeds for testing many of the ideas that emerge from basic research in information technology.

As stated at the outset the SSI is an integrated initiative from the Office of Science. The descriptions of the various components, corresponding to the goals are included in the budgets of the responsible offices. The SSI has five principal objectives:

- **Revolutionize scientific research by the application of teraflop computational resources.** Whereas the scientific accomplishments of this century have resulted in seeking and understanding the fundamental laws that govern our physical universe, the science of the coming century will be characterized by synthesis of this knowledge into predictive capabilities for understanding and solving a wide range of scientific problems, many with practical consequences. In this endeavor, the computer will be a primary instrument of scientific discovery. Many areas of scientific inquiry critical to the Department's mission will be advanced dramatically with access to teraflop scale computing including but not limited to materials sciences, structural genomics, high energy and nuclear physics, subsurface flow, and fusion energy research.
- **Discover, develop and deploy crosscutting computer science and applied mathematics technology.** The practical and intellectual challenges to making effective use of terascale computers require the development of a terascale technology base in software, networking, data management and visualization, communications, and operating environments to enable scientists to make effective use of the simulation infrastructure.
- **Establish a national terascale distributed scientific simulation infrastructure.** This network of terascale computers, ultra-high speed communications, science centers, and support centers in academia, the national laboratories, and industry will provide the advanced computing testbeds which enable the accomplishment of the first three objectives.
- **Understand, model, and predict the effects on the earth's global environment of atmospheric greenhouse gas emissions, with an emphasis on carbon dioxide.** Through the use of teraflop scale computers, accelerate progress in general circulation model development and application to reduce substantially the uncertainties in decade-to-century model-based projections of global environmental change and to increase the utility of such projections to the broad research community. Current models of global systems cannot presently achieve regional specification in global environmental change projections with the requisite accuracy and reliability needed to support national and international energy and environmental policies. Work towards this objective will also play a significant role in defining, testing, and integrating the SSI facilities and SSI crosscutting computer science and applied mathematics technologies into tools for scientific dsicovery.
- **Understand, model, and predict the behavior and properties of combustion processes and devices.** With teraflop scale computing resources and a concerted research program in combustion modeling, develop a new generation of combustion modeling tools for accelerated design of combustion devices meeting national goals of emission reduction and energy conservation. Through provision of a comprehensive understanding of the details of combustion, design engineers will have the computational tools to predict the chemical outcome of combustion processes with practical reliability, thus avoiding a time consuming, trial and error approach to the

design of combustion devices (gas turbines, internal combustion engines, etc.) Work towards this objective will also play a significant role in defining, testing, and integrating the SSI facilities and SSI crosscutting computer science and applied mathematics technologies into tools for scientific discovery.

This initiative is a part of the broader President's ITRI. The Department's primary focus is advancing science through terascale computing. To accomplish these goals, DOE will partner with other agencies, particularly the National Science Foundation, to leverage the strengths of both agencies. In the case of research in global systems the research is already part of a broad interagency effort coordinated under the U.S. Global Change Research Program (USGCRP). Computer science and enabling technologies activities have been coordinated between agencies through the Computing, Information, and Communications R&D Subcommittee of the NSTC for a number of years. As a part of this initiative, closer ties will be established between DOE-funded activities and activities funded by other agencies. The development of enabling technologies for SSI will also be coordinated with the development of related technologies for ASCI through a joint CTR - ASCI research management committee. Where appropriate, joint interagency programs in other scientific disciplines may be established.

The CTR budget includes descriptions of the SSI computational science and enabling technology, as well as advanced computing and communications facilities elements of the SSI. In addition, the CTR budget includes funding for the competitive, peer reviewed selection of a small number of basic science applications to complement the two larger integrated applications efforts. The description of the Global Systems element of the SSI is included in the Biological and Environmental Research (BER) budget and the description of the Combustion Systems element is included in the Basic Energy Sciences (BES) budget. For reference, a high level summary of the proposed budget for the entire SSI initiative is given in the table below. These amounts will be reduced for the required SBIR/STTR assessments of 2.65%.

Objective	Program	FY 2000 Request
Earth's Global Environment	Biological and Environmental Research	$10 million
Combustion Systems	Basic Energy Sciences	$7 million
Basic Science Applications	Computational and Technology Research	$6 million
Computer Science and Enabling Technology	Computational and Technology Research	$16 million
SSI Facility Operations	Computational and Technology Research	$30 million
Staffing Resources	Science Program Direction	$1 million
Total SSI		$70 million

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Computational and Technology Research					
Mathematical, Information, and Computational Sciences	124,026	139,300	-466	138,834	184,575
Laboratory Technology Research . . .	15,379	16,200	-58	16,142	14,300
Advanced Energy Projects	7,374	2,500	-5	2,495	0
Subtotal, Computational and Technology Research	146,779	158,000	-529	157,471	198,875
Use of Prior Year Balances	-1,714[a]	-1,573[a]	0	-1,573[a]	0
General Reduction	0	-529	+529	0	0
Total, Computational and Technology Research	145,065[b]	155,898	0	155,898	198,875

Public Law Authorization:

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

[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 $3,582,000 which has been transferred to the SBIR program and $215,000 which has been transferred to the STTR program.

Funding by Site

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	%Change
Albuquerque Operations Office					
Los Alamos National Laboratory	14,614	13,034	10,894	-2,140	-16.4%
National Renewable Energy Laboratory	498	127	0	-127	-100.0%
Sandia National Laboratories	5,232	5,293	3,779	-1,514	-28.6%
Total, Albuquerque Operations Office	20,344	18,454	14,673	-3,781	-20.5%
Chicago Operations Office					
Ames Laboratory	2,290	1,939	1,490	-449	-23.2%
Argonne National Laboratory	16,869	15,430	13,176	-2,254	-14.6%
Fermi National Accelerator Laboratory	100	50	332	+282	+564.0%
Brookhaven National Laboratory	2,843	1,457	2,589	+1,132	+77.7%
Princeton Plasma Physics Laboratory	90	121	332	+211	+174.4%
Total, Chicago Operations Office	22,192	18,997	17,919	-1,078	-5.7%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	57,916	53,938	49,377	-4,561	-8.4%
Lawrence Livermore National Laboratory . . .	2,755	2,940	640	-2,300	-78.2%
Stanford Linear Accelerator Center	980	357	782	+425	+119.0%
Total, Oakland Operations Office	61,651	57,235	50,799	-6,436	-11.2%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science & Education. . .	335	0	244	+244	+100.0%
Oak Ridge National Laboratory	19,434	10,415	6,876	-3,539	-34.0%
Thomas Jefferson National Accelerator Facility	190	100	283	+183	+183.0%
Total, Oak Ridge Operations Office	19,959	10,515	7,403	-3,112	-29.6%
Richland Operations Office					
Pacific Northwest National Laboratory	4,188	3,238	3,584	+346	+10.7%
All Other Sites[a]	18,445	49,032	104,497	+55,465	+113.1%
Subtotal, Computational and Technology Research	146,779	157,471	198,875	+41,404	+26.3%
Use of Prior Year Balances	-1,714[b]	-1,573 [b]	0	+1,573[b]	+100.0%
Total, Computational and Technology Research	145,065[c]	155,898	198,875	+42,977	+27.6%

[a] Funding provided to laboratories, universities, industry, other Federal agencies and other miscellaneous contractors.

b 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.

c Excludes $3,582,000 which has been transferred to the SBIR program and $215,000 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 also 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 also 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 also 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 CTR 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 also 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 also 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 CTR program funds research at 71 colleges/universities located in 24 states. This line also includes funding of research awaiting distribution pending completion of peer review results.

Mathematical, Information, and Computational Sciences

Mission Supporting Goals and Objectives

The Mathematical, Information, and Computational Sciences (MICS) subprogram supports advanced computing research — applied mathematics, high performance computing, and networking — and operates supercomputer and associated facilities that are available to researchers 24 hours a day, 365 days a year. The combination of support for fundamental research, computational and networking tools development, and high-performance computing facilities provides scientists with the capabilities to analyze, model, simulate, and — most importantly — predict complex phenomena of importance to the Office of Science and to the Department of Energy.

Examples of the complex problems addressed by the Office of Science and the Department of Energy are: climate modeling, including the effects of greenhouse gases on global climate change; the combustion process, including the simulation of combustion in devices such as diesel engines; the subsurface transport of pollutants; the rational design of new materials to produce, for example, new alloys, superconductors, polymers, and catalysts; the effects of aging on the nuclear stockpile; and the analysis of vast amounts of real data from experiments at the Office of Science facilities for high energy physics, nuclear physics, materials sciences, chemical sciences, structural biology, and other disciplines.

For many such problems, traditional theoretical and experimental approaches may not be suitable; theory may be inadequate to handle the complexity, and experiments may not be feasible, because they are too dangerous, too expensive, or simply impossible owing to the length and time scales involved. Furthermore, experiments at the Office of Science facilities may generate millions of gigabytes (petabytes) of data per year (which would fill the disk drives of millions of today's personal computers) presenting significant computational and communications challenges in analyzing and extracting understanding from the data.

The increases in computational and communications capabilities achieved over the past two decades have made simulation a third branch of science that now complements theory and experiment and allows a new approach to previously intractable problems. However, as computational and communications capabilities have increased, so too have the challenges associated with effectively using these capabilities. The rate of increase in these capabilities itself poses formidable challenges. Significant hardware changes can occur as often as every 18 months; these, in turn, may require completely new approaches to computing software. This has already changed the way in which computation is performed in scientific disciplines such as materials science, biology, and fusion energy. Teams involving scientists from the disciplines as well as mathematicians; computer scientists; and experts in computer graphics, data management, and advanced computer networks are now required to address scientific problems that make use of the most modern computer and communications capabilities. This situation is quite different from that of even ten years ago when individual scientists could code and perform calculations with little or no support from others.

These same increases in computational and communications capabilities are having a second important impact on the way science is conducted. It is now possible for large geographically distributed teams to easily and effectively collaborate using major experimental facilities, computational resources, and data resources. The name given to such optimized linkages among geographically distributed resources is "collaboratories." In the coming years, they are expected to play an increasingly important role in the Nation's scientific enterprise.

In order to enable scientists in the Office of Science to make effective use of these capabilities, the MICS subprogram supports research in three areas:

- Applied Mathematics. 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. 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. 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.

In all of these areas — applied mathematics, computer science, and networking — the requirements far exceed the current state-of-the-art; furthermore, the requirements far exceed the tools that the commercial marketplace will deliver. In addition to these fundamental research efforts, the MICS subprogram takes the results of these efforts and forms partnerships with users in scientific disciplines to validate the usefulness of the ideas and to develop them into tools. MICS also provides the advanced computing and communications facilities that enable scientists to use these tools.

MICS provides two types of advanced computing and communications facilities. The first type of facility enables scientists to use the tools developed. Examples are NERSC and ESnet. The second type of facility is itself a research project. The principal current examples of this type of facility are the Advanced Computing Research Facilities (ACRFs) at Argonne National Laboratory, Lawrence Berkeley National Laboratory, and Los Alamos National Laboratory that represent the evolution of the High Performance Computing Research Centers and were established as part of the High Performance Computing and Communications initiative. The ACRFs combine research in computer software and hardware with targeted applications. One of the major issues that these facilities attempt to address is how different choices in computer architecture affect the ability of a system to scale to very large numbers of processors and very high performance. In order to address these issues, computers at a scale that push the state-of-the-art must be sited at the ACRFs. These computers enable research in computers and computing, but they are not sufficiently mature or robust for production computing by large numbers of users.

Partnerships with the scientific disciplines are an important management philosophy in the MICS subprogram. 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. Finally, to develop future generations of scientists with the breadth of skills required to be effective both in advanced computing research and in interacting with disciplinary sciences, MICS supports the Computational Science Graduate Fellowship program.

The MICS subprogram includes the Department's participation in the President's Next Generation Internet (NGI) Initiative. This initiative will create the foundation for more powerful and versatile networks of the 21st century, just as previous federal investments in information technology R&D created the foundation for today's Internet. DOE's participation in this initiative is focused on network requirements that will enable data-intensive scientific research not now possible because of network limitations. It is anticipated that the results and “spinoffs” of this research, after testing and prototyping by the scientific community, will impact broad commercial use of networks.

DOE's NGI research program is focused on discovering, understanding, developing, testing and validating the networking technologies needed to enable wide area, data intensive and collaborative computing that is not currently possible. This program will integrate scientists working on fundamental research in applied mathematics, computer science, and networking with scientists working on DOE applications to develop new ways to link scientists with DOE's major scientific user facilities and computational centers. Such research is needed to enable effective use of petabyte/year High Energy and Nuclear Physics facilities such as the Relativistic Heavy Ion Collider (RHIC); to provide remote visualization of terabyte to petabyte data sets from computational simulation; to develop advanced collaboratories; and to enable effective remote access to tomorrow's advanced scientific computers. These applications share two important characteristics. They all involve extremely large data sets, and they all require that scientists be able to interact with the data in (nearly) real time. Current network technology limitations significantly limit our ability to address either of these characteristics.

The NGI activities are critical for DOE's fundamental science research. 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. Management of scientific data is further complicated because the data must be managed in large units. This is very different than data management in the commercial sector. For example, a standard telecommunications billing record is only 180 bytes long; a large web page is 500 kilobytes; but the data from a global climate model at any given time during the simulation (a single time step) may be greater than a gigabyte or 2,000 times as large as that of a large web page!

The technologies developed for commercial network traffic are simply inadequate for scientific network traffic. Significant *research* is needed to enable today's commercial networks to be used for scientific data. This research must include advanced protocols, special operating system services for very high speed, and very advanced network control. For example, a coast to coast gigabit/second network may have as much as a gigabit of data in transit at any one time. If this is scientific data this might be one packet. Current protocols would require that all of the switches along the way be able to buffer a gigabit of data at very high rate, which is not possible with today's switches. Therefore research is required. The issues related to managing a single gigabit packet versus 2,000 500 kilobit packets are very different.

In addition to the complications posed by the transmission of large data sets, there are additional complications that result from the many different kinds of network devices, network-attached devices, and services that need to be integrated together. 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. This type of integration, as well as the issues of improving the performance of the individual components, all require significant research because the issues are currently not well understood. Indeed, the first identification of many of these issues is the result of previous work in collaboratories and visualization supported by this subprogram. Thus DOE's participation in the NGI builds on previous results of the MICS subprogram to address critical issues in the network. Furthermore, the differences between the requirements of commercial networks and networks for scientific research require DOE to conduct this research because these tools and technologies will not be developed by commercial R&D. However, there will be tremendous “spinoff” benefits to the Internet in general after the research is completed and the results enhance commercial networks.

Scientific Simulation Initiative

This budget also includes the MICS subprogram’s contribution to DOE’s Scientific Simulation Initiative (SSI), an integrated effort bringing together computational and communication resources, focused research in scientific disciplines, and research in computer science and other enabling technologies to solve the complex problems that characterize DOE’s scientific research needs. The SSI couples research in advanced scientific applications in the programs of the Office of Science with research in computer science and enabling technologies and advanced computing and communications facilities. It is a joint program between CTR and the other program offices in SC.

It is a requirement for the success of this program to use the expertise that exists in national laboratories, universities, and industry and, where appropriate, formation of multidisciplinary teams of researchers. Participants from various institutions will be encouraged through open peer reviewed competitions. Also, strong partnerships with the DOE ASCI program and complementary programs in other agencies will be essential. The overview of the integrated program is given in the Program Mission statement of the CTR budget; however, the specific contributions of the MICS subprogram are described below.

MICS contributes to the SSI in three ways:

Management of the Computer Science and Enabling Technology (CSET) component of the SSI;

Management of the SSI Advanced Computing and Communications Facilities; and

Management of the peer reviewed selection process for the basic science application efforts to be initiated in FY 2000.

The goal of the CSET component of the SSI is to develop needed software systems, to deploy these systems into the DOE computing infrastructure, to support users, and to conduct the needed research to address future problems, all with close involvement of the applications scientists and the computer systems providers. CSET teams will also work closely with the vendor community to ensure that needed capabilities are incorporated into products, systems, and services. Working with the university research community, CSET teams will ensure a steady flow of young researchers into the field and will form long-term collaborations in the areas needed by scientific simulation. CSET teams will also establish natural partnerships with the DOE ASCI program and with the NSF Partnerships for Advanced Computational Infrastructure (PACI) program, which are addressing complementary goals. These partnerships could result in the joint funding of research and development activities and joint deployment of infrastructure capabilities. CSET is a critical crosscutting activity for the Scientific Simulation Initiative — one that will enable the program to accomplish far more than if applications teams were required to develop all the necessary software and infrastructure themselves. Through the sharing of common tools and technologies, the CSET activities will dramatically improve the cost-effectiveness of the SSI. In order to accomplish these goals, CSET must support a vigorous research program as well as significant development and software deployment activities to address the following critical issues.

First, despite considerable progress during the past ten years in making massively parallel computer systems usable for applications, much remains to be done. Computer systems targeted for SSI will scale from approximately 1,000 nodes today to 5,000 or 10,000 nodes for systems in 2004. This scaling will require substantial improvements in parallel computing tools, parallel I/O (input/output) systems, data management, algorithms, and program libraries. Not only will the number of compute nodes increase, but the nodes themselves will become more complex, as systems 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 showing their roots in today's systems, will be substantially different and substantially more complex and therefore more challenging to exploit for high performance.

Second, because applications software systems typically outlive hardware by an order of magnitude (i.e., computer hardware typically has a useful lifetime of three years, whereas large-scale scientific codes last one to two decades), new software must be designed for machines not only for the near future but for the next decade. This effort will require close working relationships between code developers from the applications areas and computer scientists who are involved in next-generation systems and architecture design.

Third, the applications themselves are getting more complex. They are incorporating more sophisticated physical models, are using advanced numerical techniques (e.g., adaptive mesh refinement, unstructured and implicit solvers, and hierarchical methods), and are beginning to be combined into large-scale “simulation systems” that include the linkage of two or more previously stand alone models (e.g., ocean-atmosphere-biosphere or fluid-structures-chemistry). Furthermore, in some cases these models are being driven by an optimization environment to enable them to address policy questions.

Finally, in addition to rapidly changing hardware and applications targets, the user and development community is also evolving. No longer can groups afford to work only with local collaborators or to use only locally available hardware and software resources. The development and user environments of the near future will need to enable ubiquitous collaboration and distributed computing capabilities to address these complexities. As the applications codes themselves become more interdisciplinary, so too will the teams that write them. As the need to incorporate deep knowledge of computer science techniques into future codes increases, so will the need to form long-term collaborations among applications scientists and computer scientists and mathematicians. These unavoidable trends mean that the problem-solving environments of the future will need to support human-to-human interactions as easily as we support computer to computer interactions today.

The management of SSI Computing and Communications facilities also poses challenges. Specifying, developing procurement specifications for, and finally delivering installed SSI facilities require great skill and experience. All of the facilities must work together because the performance of the system is determined by the slowest component. The SSI facilities must provide the linkage between the computing environment developed for the user and the systems management and systems integration required to support these environments. The SSI requires three distinct types of computing facilities: computing, networking and associated supporting hardware.

DOE will establish an open solicitation process that seeks the widest participation in establishing its terascale computing infrastructure, including competition among national laboratories, universities, and industry, based on their qualifications. The sites for the major teraflop computers will be selected through peer-reviewed competition. A number of considerations are important in selecting organizations to manage and locations at which to site SSI facilities. One of the most important is an expertise to perform the necessary computing systems integration into the existing nationwide DOE Office of Science computing infrastructure. These large-scale systems have requirements for scalable systems management that will enable relatively small systems administration teams to manage systems with 1000's of nodes and 10,000's of processors. These systems also need to be tightly integrated with data storage environments, mass stores, visualization environments, and distributed computing frameworks. Other considerations include incremental site preparation costs, the cost of connecting at very high speed to the networking infrastructure, and site financial leverage in providing operational support to the facility.

Finally, MICS will manage the open peer reviewed competition among basic science disciplines to select a small number for initial inclusion in the initiative. These applications will be chosen from throughout the portfolio of the Office of Science based on the scientific and technical merit of the proposals; the importance to DOE missions; and the readiness of the area and the associated scientific communities to move quickly to terascale computers.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Mathematical, Computational, and Computer Sciences Research	47,857	51,560	71,407	+19,847	+38.5%
Advanced Computation, Communications Research and Associated Activities	76,169	83,800	108,682	+24,882	+29.7%
SBIR/STTR	0	3,474	4,486	+1,012	+29.1%
Total, Mathematical, Information, and Computational Sciences	124,026	138,834	184,575	+45,741	+32.9%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000

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. This activity supports research at DOE laboratories, universities, and private companies to provide the DOE laboratory community and the wider national scientific and engineering communities with the most powerful and effective mathematical and computational tools for modeling, analyzing, and simulating complex phenomena in the core disciplinary and technology areas of DOE. Laboratory, academic, and industry researchers supported by the program work at laboratory sites with DOE mentors. 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, distributed computing, 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** including hyperbolic systems, multipole expansions, mixed elliptic-hyperbolic problems, 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 2000 budget includes the continuation of work initiated in FY 1999

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
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, environmental remediation, and stockpile stewardship. CTR will provide opportunities for college faculty and students to spend time at DOE laboratories, to participate in world-class research projects. Faculty/Student Science Teams will visit DOE labs during the academic/summer semesters, be involved in conducting research, writing proposals, utilizing technology and pursuing technical or scientific careers. Primary goals of the Science Teams are to build long-term partnerships among DOE laboratories and provide faculty/students with a deeper understanding of DOE science associated needs for research and development. Funds will be provided to pay for faculty/student stipends, travel, housing, and subsidizing laboratory scientists' time for this activity ($1,947,000).	23,576	25,232	27,179
■ **Computer Science:** Research in computer science to enable large scientific applications. 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 for message passing and parallel input/output (IO) as well as tools to monitor the performance of scientific applications. The second area includes research in effective techniques for retrieving data with complex internal structure from massive data archives that may be geographically distributed as well as advanced techniques for visualizing very large scale scientific data.	14,000	14,000	14,000

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Advanced Computing Software Tools:** R&D to develop the results of fundamental research in applied mathematics and computer science into an integrated set of tools that can be used by scientists in various disciplines to develop high performance scientific applications (e.g., to simulate the behavior of materials) that will have a useful life spanning many generations of computer hardware. These tools will include capabilities for representing complex geometries, solving diverse numerical equations, simplifying multi-language parallel execution, evaluating and enhancing code performance, and dynamically steering calculations during execution. This effort began as a part of the DOE2000 initiative.	5,000	5,000	5,000
■ **Scientific Applications Pilot Projects:** R&D to apply 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. Examples of pilot projects include: research in simulations of the earth's climate; research in the fundamental structure and properties of magnetic materials; creation of advanced tools to understand the chemistry of actinides; and partnerships with experimental disciplines such as high energy and nuclear physics, human genomics, and crystallography to improve the ability of these disciplines to manage and analyze the petabytes of data (that would fill the hard disks of millions of today's PC's) produced by their experiments and simulations. These efforts represent the evolution of the Grand Challenge projects that were initiated as part of DOE's component of the Federal High Performance Computing and Communications program, which started in FY 1991. These projects will now be phased out in an orderly manner	5,281	7,328	3,785

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Scientific Simulation Initiative (SSI) Algorithms, Models, Methods and Libraries:** New classes of algorithms will need to be developed to effectively utilize SSI systems. SSI computers will be characterized by large-scale distributed shared memory, with deep memory hierarchies. To achieve maximum performance, new hierarchical algorithms and methods need to be developed that can take advantage of these architecture features. In addition, mathematical techniques that are already under development may yield fundamentally new ways to conduct individual simulations and ensemble calculations, improving predictability and our understanding of errors in computations. New strategies for building mathematical software based on components are also likely to make a large contribution to programmer effectiveness for the SSI applications.	0	0	2,947
■ **SSI Problem Solving Environments and Tools (PSET):** A major challenge for CSET will be the development of an integrated problem solving environment that supports the rapid construction and testing of applications codes. These environments need to support the most advanced parallel tools and libraries and enable users to collaborate on the development of codes, planning runs, debugging and performance analysis. PSET systems will also allow the user to monitor jobs visually and to steer computations from their desktop and to share these results with others.	0	0	2,920
■ **SSI Distributed Computing and Collaboration Technology (DCCT):** Many SSI applications teams will be distributed around the country. They need the capability to work together not only to develop codes, but also to share data, design experiments, plan work and jointly conduct long running jobs. DCCT will support the creation of a software technology base to support SSI simulations that will enable users to run jobs at remote sites and migrate data from one site to another. Distributed computing technology will enable users to begin to see a single logical view of the DOE computing infrastructure and request, coordinate, and manage resources from multiple sites to attack a problem.	0	0	2,920

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **SSI Visualization and Data Management Systems:** Simulations run on 10 teraflop or 40 teraflop class computers will generate 10's or 100's of Terabytes of output per job. Advanced scientific visualization and analysis systems will be needed to translate this mass of output to human understanding. Some data will best be analyzed visually while other data will need to be post-processed to extract features and statistics. Both forms of analysis will need sophisticated data management systems to enable the rapid and facile manipulation of datasets. Large-scale databases will be used to manage data from simulations and advanced data organization techniques will support rapid and hierarchical traversals of data providing the user the possibility of flying through data in real-time. Associated capital requirements for large scale data management and visualization testbeds are also supported . . .	0	0	6,815
■ **SSI Basic Science Applications:** Support two basic science SSI application efforts. These efforts will be selected through a competitive process that evaluates the scientific and technical merit of the proposed project, the potential of the proposed work to make significant new science possible, and the readiness of the scientific discipline and associated scientific community to make early use of terascale computers.	0	0	5,841
Total Mathematical, Computational, and Computer Sciences Research	47,857	51,560	71,407
Advanced Computation, Communications Research, and Associated Activities			
■ **Networking:** Research in high performance computer networks and information surety 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 to enable applications to request, and be guaranteed, certain levels of network capability.	5,987	4,500	4,500

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ **Collaboratory Tools:** R&D to develop the results of fundamental research in computer science and networking into an integrated set of tools to enable scientists to remotely access and control facilities and share data in real time. In order to accomplish this goal a number of issues are under investigation including: definition and demonstration of a general and modular security architecture that can protect open network applications such as control of experimental devices; development of a modular electronic notebook prototype that can be used in a number of desktop computer environments to enable the sharing of scientific results, data from scientific instruments, and design of scientific procedures; development of tools to manage distributed collaborations such as tools for managing multipoint videoconferences ranging from the current "whoever is speaking has the floor" to more formal meetings where a meeting leader controls who has the "floor"; development of advanced techniques for managing and returning to the electronic record of the collaboration; and exploration of techniques such as virtual reality to enable large groups to work together effectively at a distance. This effort began as a part of the DOE2000 initiative.	3,000	3,000	3,000
■ **National Collaboratory Pilot Projects:** R&D to test, validate, and apply collaboratory tools in partnership with other DOE programs. The two pilot projects are: (1) the Materials MicroCharacterization Collaboratory, a partnership with Basic Energy Sciences 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 the research and researchers at Sandia National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and the University of Wisconsin with efforts and researchers at industrial			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
laboratories in Indiana and Michigan to develop the next generation of clean diesel engines. This effort began as a part of the DOE2000 initiative. These partnerships with the scientific disciplines and the technology programs enable MICS to be particularly successful in bringing advances in advanced computing research to bear on important problems faced by scientists in other disciplines. In addition, they provide important feedback to the researchers on what problems are most important.	3,000	3,000	3,000
■ **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 3,500 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. These computational resources will be integrated by a common high performance file storage system that facilitates interdisciplinary collaborations. This file storage system, the Archival Systems Upgrade, is a major item of equipment in FY 2000 with a total estimated cost of $2,000,000.	26,500	26,500	27,500
■ **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. Because many of the issues to be investigated only appear in the computer systems at significantly larger scale than the computer manufacturers' commercial design point, these facilities must procure and develop software to manage and make useful the largest scale systems that can be afforded. 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.			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Therefore, all of these systems are managed as research programs and not as information technology investments. 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 Next Generation procurement). Related capital equipment needs such as high speed disk storage systems, archival data storage systems and high performance visualization hardware are also supported. The ACRFs represent the evolution of the High Performance Computing Research Centers that DOE initiated as a part of the Federal High Performance Computing and Communications initiative.	22,895	17,411	11,876

- **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 National Science Foundations's very high performance backbone network service that provides high performance connections to many research universities. One 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

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
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. Related capital equipment needs are also supported such as high speed network routers, ATM switches, and network management and testing equipment.	14,787	14,787	14,787

- **Next Generation Internet (NGI):** DOE's program will focus on developing, testing and validating the networking technologies needed to enable wide area, data intensive and collaborative computing. The program, which began in FY 1999, has three subcomponents. First, research in basic underlying technologies such as: protocols and techniques for coordinating multiple, heterogeneous network-attached devices; congestion and flow control techniques; multi-gigabit end system interfaces, analyzers, and switches along with mechanisms to reduce operating system overhead for data transfers; mechanisms to provide application controlled Class of Service and Quality of Service; and middleware to provide Internet Protocol (IP), ATM, and WDM resource and admission control, scheduling, management, prioritization, accounting, and debugging. Second, Application-Network Technology-Network Testbed Partnerships to: integrate and test advanced network R&D and testbeds with DOE mission applications such as HENP Data, remote visualization of simulation results, advanced collaboratories; define what network & middleware services are required to permit these applications to effectively run over wide area networks; define the features and the API's necessary to allow the application and middleware to communicate; integrate local and wide-area network technologies to create distributed collaboratories; and integrate Differentiated Services, or other Quality of Service functions, into wide area networks and production network testbeds without compromising the existing production network services. Third, DOE-University Technology Testbeds focused on: R&D to implement advanced network services across multiple, interconnected networks; deployment of advanced differentiated services technology

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
across autonomous networks when priority flow represents a significant fraction of the available capability; development and testing of advanced tools to manage "peering" of networks with advanced services; cross-domain implementations of security and authentication technologies; development and testing of network performance monitoring and characterization software which applications can use in this environment to optimize their performance; and development of policy frameworks and specification languages to facilitate the negotiation of capabilities across autonomous system boundaries.	0	14,602	14,602
■ **SSI Research Computing Facilities and Network Infrastructure:** Initiation of a procurement for one 5 Teraflop-class computer system and associated data archive facilities in the third quarter of FY 2000. This activity includes not only procurement of the computing and storage systems but also the associated operational costs and facility improvements which will be required. This process will have two distinct stages. DOE will establish an open solicitation process that seeks the widest participation in establishing its terascale computing infrastructure, including competition among national laboratories, universities, and industry, based on their qualifications. The sites for the major teraflop computers will be selected through peer-reviewed competition. A number of considerations are important in selecting organizations to manage and locations at which to site SSI facilities. One of the most important is an expertise to perform the necessary computing systems integration into the existing nationwide DOE Office of Science computing infrastructure. These large-scale systems have requirements for scalable systems management that will enable relatively small systems administration teams to manage systems with 1000's of nodes and 10,000's of processors. These systems also need to be tightly integrated with data storage environments, mass stores, visualization environments, and distributed computing frameworks. Other considerations include incremental site preparation costs, the cost of connecting at very high speed to the networking infrastructure, and site			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
financial leverage in providing operational support to the facility. After the site is selected, the site must conduct an open competition to procure the 5 teraflop-class computer system as well as the other supporting computing and data storage systems. This activity also includes significant enhancements to the ESnet infrastructure to support access to the SSI computer facility by SSI scientists. SSI computing facilities and remote sites require very high performance network facilities to be effective. Planning estimates indicate that aggregate network data flow into and out of SSI facilities must be near 100 gigabits/second, almost 200 times faster than the fastest links on today's ESnet. In addition, remote sites with major participation in SSI science areas and CSET require significantly greater network capabilities than ESnet can provide within its current funding profile. Enhanced network services will be provided to remote sites on the basis of need and the resources available. The balance of funding between the computer facility and enhanced networking will be determined by detailed review after the selection of the computer facility site. However, preliminary estimates indicate that the computer facility will require between 80 percent and 85 percent of the funding in this activity. Associated requirements for capital equipment and GPP funding are included here..	0	0	29,417
Total, Advanced Computation, Communications Research, and Associated Activities	76,169	83,800	108,682
SBIR/STTR			
■ In FY 1998, $3,004,000 and $180,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	3,474	4,486
Total, Mathematical, Information, and Computational Sciences	124,026	138,834	184,575

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Mathematical, Computational, and Computer Sciences Research	
■ Increase in funding will provide opportunities for college faculty and students to spend time at DOE laboratories to participate in world class research projects.	+1,947
■ Close out all scientific application pilot projects in an orderly fashion in mid-FY 2000.	-3,543
■ Initiate support for SSI's Computational Sciences and Enabling Technology and Basic Science Applications..	+21,443
Total, Mathematical, Computational, and Computer Sciences Research	+19,847
Advanced Computation, Communications Research, and Associated Activities	
■ Cost-of-living increase for operations of NERSC.	+1,000
■ Reduced support for ACRF's including termination of the ACRF at ANL in mid-FY 2000.	-5,535
■ Support for SSI's Research Computing Facilities and Network Infrastructure. . .	+29,417
Total, Advanced Computation, Communications Research, and Associated Activities	+24,882
SBIR/STTR	
■ Increase in SBIR/STTR due to increase in operating expenses.	+1,012
Total Funding Change, Mathematical, Information, and Computational Sciences . .	+45,741

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.

Performance Measures

- Initiate about 7 Laboratory Technology Research projects that address the Department’s top priorities for science and technology, through cost-shared research partnerships with industry.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Laboratory Technology Research	14,983	12,751	13,921	+1,170	+9.2%
SBIR/STTR	0	423	379	-44	-10.4%
Congressional Direction	396	2,968	0	-2,968	-100.0%
Total, Laboratory Technology Research	15,379	16,142	14,300	-1,842	-11.4%

Detailed Program Justification

(dollars in thousands)

	FY 1998	FY 1999	FY 2000

Laboratory Technology Research

- This activity supports research to advance the fundamental science and technology 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. In FY 2000, about 7 new Laboratory Technology Research projects will be initiated. The research portfolio consists of approximately 100 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 process to produce ultra-smooth diamond coatings on rotating and sliding mechanical parts in order to reduce energy consumption, improve product reliability, and reduce toxic emissions to the environment; (2) a new family of wireless, single-chip luminescent-sensing devices for use in monitoring of environmental pollutants and in high throughput screening of new therapeutic drugs; and (3) an x-ray imaging module, consisting of a cadmium zinc telluride detector and an application-specific integrated circuit, to determine bone density in the diagnosis of osteoporosis by performing whole

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
body scans with lower dose rate and higher resolution. 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 an industry. Recent projects supported the development of (1) a low-temperature oxygen plasma technology for remediation of soils contaminated by pesticides and other chemicals; (2) a new class of fluids that can transfer heat more efficiently than conventional fluids and offer several energy-related benefits, including decreased pumping power needs and reduction in required heat exchanger size, for use in the transportation, electronics, and textile industries; and (3) improved catalytic materials, which can lead to substantial energy savings in petroleum refining and chemical manufacturing.	14,983	12,751	13,921
SBIR/STTR			
■ In FY 1998, $391,000 and $24,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	423	379
Congressional Direction			
■ Funds the University of Southwestern Louisiana (per FY 1997 Congressional Direction).	396	2,968	0
Total, Laboratory Technology Research	15,379	16,142	14,300

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Laboratory Technology Research	
■ Increase in multiyear technology research partnership projects.	+1,170
SBIR/STTR	
■ Decrease in SBIR/STTR due to decrease in operating expenses.	-44
Congressional Direction	
■ Reduction is due to completion of Congressionally directed projects	-2,968
Total Funding Change, Laboratory Technology Research.	-1,842

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 1998	FY 1999	FY 2000	$ Change	% Change
Advanced Energy Projects	7,374	2,429	0	-2,429	-100.0%
SBIR/STTR	0	66	0	-66	-100.0%
Total, Advanced Energy Projects	7,374	2,495	0	-2,495	-100.0%

Detailed Program Justification

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
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.	7,374	2,429	0

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
SBIR/STTR			
■ In FY 1998, $187,000 and $11,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 amount is the estimated requirement for the continuation of the SBIR and STTR programs.	0	66	0
Total, Advanced Energy Projects	7,374	2,495	0

Explanation of Funding Changes From FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Advanced Energy Projects	
■ Termination of existing AEP program. The decision to terminate the AEP subprogram resulted from a change in CTR program priorities	-2,429
SBIR/STTR	
■ Decrease in SBIR/STTR due to termination of the program.	-66
Total Funding Change, Advanced Energy Projects	-2,495

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
General Plant Projects	397	70	4,000	+3,930	+5,614.3%
Capital Equipment (total)	6,912	6,275	11,275	+5,000	+79.7%
Total, Capital Operating Expense	7,309	6,345	15,275	+8,930	+140.7%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1998	FY 1999	FY 2000	Accept-ance Date
Archival Systems Upgrade - LBNL	2,000	0	0	0	2,000	FY 2002
Total, Major Items of Equipment		0	0	0	2,000	

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 also provides funding 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.

Program Goal

To ensure that the support facilities at the multiprogram laboratories can 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.

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 laboratories.
- To promote performance-based infrastructure management.

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.

  Expectation: Fund highest priority needs based on scoring from Life Cycle Asset Management (LCAM) Cost-Risk-Impact Matrix.

- Overall condition of laboratory buildings.

  Expectation: Increase the percentage of facilities rated adequate.

- Excellence in project management.

  Expectation: Increase the percentage of projects completed within baseline cost and schedule.

Significant Accomplishments and Program Shifts

- Progress in Line Item Projects - Two projects are scheduled for physical completion in FY 2000: the Building Electrical Services Upgrade- Phase I at ANL-E and the Electrical Services Rehabilitation-Phase IV at LBNL.

- Continue the Payments in Lieu of Taxes (PILT) for ANL-E and BNL.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Multiprogram Energy Laboratories-Facilities Support					
Multiprogram Energy Laboratories-Facilities Support	21,247	21,260	0	21,260	21,260
Use of Prior Year Balances	-336[a]	-13[a]	0	-13[a]	0
Total, Multiprogram Energy Laboratories-Facilities Support	20,911	21,247	0	21,247	21,260

Funding by Site

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Chicago Operations Office					
Argonne National Laboratory	10,892	7,359	5,246	-2,113	-28.7%
Brookhaven National Laboratory	568	2,239	7,775	+5,536	+247.2%
Total, Chicago Operations Office	11,460	9,598	13,021	+3,423	+35.7%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	2,400	4,854	6,133	+1,279	+26.3%
Oak Ridge Operations Office					
Oak Ridge National Laboratory	7,387	6,808	2,106	-4,702	-69.1%
Subtotal, Multiprogram Energy Laboratories - Facilities Support	21,247	21,260	21,260	0	0.0%
Use of Prior Year Balances	-336[a]	-13[a]	0	+13	+100.0%
Total, Multiprogram Energy Laboratories - Facilities Support	20,911	21,247	21,260	+13	+0.1%

Public Law Authorization:

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

[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 30 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-001-03 - Electrical Systems Upgrade, Phase III (TEC $7,620,000) Project includes upgrading transmission lines, transformers, switchgear, etc. to insure system reliability.

- 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 proposed new start for FY 2000 will bring 30 major facilities into compliance with the Life Safety Code and the National Fire Alarm Code.

The program also provides funding 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 38 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 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.

The program also provides funding 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.

Oak Ridge National Laboratory

Oak Ridge National Laboratory 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 36 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:

- 94-E-363- Roofing Improvements (TEC $16,000,000) This project is replacing the roofs on numerous facilities, thereby extending their lives significantly.
- MEL-001-08 Electrical Systems Upgrade (TEC $5,900,000) This proposed new start for FY 2000 will include: replacing overhead feeders; installing advanced protective relaying capabilities at major substations; and replacing major switchgear and transformers.

Multiprogram Energy Laboratories - Facilities Support

Mission Supporting Goals and Objectives

This subprogram supports the program's goal to ensure that the multiprogram laboratories' support facilities 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 which address needs through the year 2003 based on expected programmatic support. The projected needs through the period total over $320,000,000. Of this amount, 53 percent is to rehabilitate or replace buildings; 33 percent is for utility projects; and 14 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 1998	FY 1999	FY 2000	$ Change	% Change
General Purpose Facilities	10,829	10,271	15,500	+5,229	+50.9%
ES&H	10,418	9,829	4,600	-5,229	-53.2%
Infrastructure Support	0	1,160	1,160	0	0.0%
Total, Multiprogram Energy Laboratories-Facilities Support	21,247	21,260	21,260	0	0.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
General Purpose Facilities			
■ Supports the initiation of one new General Purpose Facility subproject in FY 2000, as well as the continuation of three FY 1999 subprojects under the Multiprogram Energy Laboratories Infrastructure Project (MEL-001). The FY 2000 new start is for design activities on the Electrical Systems Upgrade at ORNL ($357,000). The FY 1999 subprojects are the Central Supply Facility at ANL-E ($3,380,000); the Electrical Systems Modifications, Phase I at BNL ($3,881,000), and the Rehabilitation of Building 77 at LBNL ($6,133,000). Also supports the ongoing Roofing Improvements Project at ORNL ($1,749,000) (94-E-363) .	10,829	10,271	15,500
ES&H			
■ Supports the initiation of one new ES&H subproject in FY 2000, as well as the continuation of one FY 1998 and one FY 1999 subproject under the Multiprogram Energy Laboratories Infrastructure Project (MEL-001). The FY 2000 new start is for design activities on the Fire Safety Improvements, Phase IV at ANL-E ($400,000). The FY 1999 subproject is the Sanitary System Modifications, Phase III at BNL ($3,000,000). Also supports the completion of the Electrical Systems Upgrade, Phase III at ANL-E ($1,200,000).	10,418	9,829	4,600
Infrastructure Support			
■ Continue meeting payments in lieu of taxes assistance requirements for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory-East.	0	1,160	1,160
Total, Multiprogram Energy Laboratories - Facilities Support	21,247	21,260	21,260

Explanation of Changes

	FY 2000 vs. FY 1999 ($000)
■ There are no changes from FY 1999 to FY 2000 for the MEL-FS program.	0
Total Funding Change, Multiprogram Energy Laboratories - Facilities Support . . .	0

Capital Operating Expenses & Construction Summary

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1998	FY 1999	FY 2000	Unapprop. Balance
MEL-001 Multiprogram Energy Laboratories Infrastructure Project	N/A	N/A	7,259	14,924	18,351	19,346
94-E-363 Roofing Improvements, ORNL . .	16,000	5,422	3,921	4,908	1,749	0
Total, Construction		5,422	11,180	19,832	20,100	19,346

MEL-001 — Multiprogram Energy Laboratories, Infrastructure Project, Various Locations

(Changes from FY 1999 Congressional Budget Request are denoted with a vertical line in the left margin.)

Significant Changes

Two new starts in FY 2000 include: Electrical Systems Upgrade, Oak Ridge National Laboratory, and Fire Safety Improvements, Phase IV, Argonne National Laboratory-East.

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	14,924	8,955
FY 2000	18,351	18,351	18,782
FY 2001	17,316	17,316	21,210
FY 2002	2,030	2,030	8,205
FY 2003	0	0	370

3. Project Description, Justification and Scope

This project funds two types of subprojects:

- Projects to correct ES&H deficiencies including fire safety improvements, sanitary system upgrades and electrical system replacements; and
- 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.

General Purpose Facility Projects:

a. Subproject 01 - Upgrade Steam Plant, ORNL

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
5,300	0	3,400	1,900	0	0	1Q 1998 - 4Q 1999

This project will upgrade 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 will be procured with all necessary ancillary equipment, such as blowers, feedwater pumps, and controls. Suitable weather protection will be provided.

This project is 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 will allow decreased firing time on the oldest boilers and will extend their useful life. In addition, the new boiler will improve the efficiency of the steam plant.

b. Subproject 04 - Electrical Systems Modifications, Phase I (BNL)

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
5,730	0	0	849	3,881	1,000	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 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 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
8,000	0	0	754	6,133	1,113	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 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
5,900	0	0	1,860	3,380	660	2Q 1999 - 2Q 2001

This project is a change in scope from the stand-alone facility of 39,100 sq.ft. described in the FY 1999 President's Request. The proposed facility is 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. This 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. This proposed scope change is a result of: process improvements that have led to a reduction in on-hand inventory, relocation of DOE records storage to off-site archives; relocation of mail services; and a reduction to the labs vehicular fleet that reduced the utilization of Bldg. 46.

e. Subproject 08 - Electrical Systems Upgrade (ORNL)

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
5,900	0	0	0	357	5,543	3Q 2000 - 2Q 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.

ES&H Projects:

a. Subproject 02 - Electrical Systems Rehab. Phase IV, (LBNL)

TEC	Prev.	FY 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
6,500	0	2,400	4,100	0	0	2Q 1998 - 4Q 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 will upgrade the existing 12 kV power system and utilize circuit breakers installed in the FY 1987 MEL-FS project improvement to the main Grizzly Substation.

The project will correct existing deficiencies in the power distribution system that serves the Blackberry Canyon Service Area. The improvements will replace the existing electrical system, which consists of aged and underrated electrical equipment, 20 to 30 years old in many instances, that is difficult to maintain and unsafe to operate. It will provide 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 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
7,620	0	1,459	4,961	1,200	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 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
6,500	0	0	500	3,000	3,000	2Q 1999 - 2Q 2002

The BNL Sanitary System consists of over 20 miles of collection piping which 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 1998	FY 1999	FY 2000	Outyear	Construction Start/ Completion Dates
8,430	0	0	0	400	8,030	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.

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

94-E-363 — Roofing Improvements, Oak Ridge National Laboratory, Oak Ridge, Tennessee

(Changes from FY 1999 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 1994 Budget Request *(Preliminary Estimate)*	1Q 1994	1Q 1995	2Q 1994	1Q 1997	16,000	16,132
FY 1996 Budget Request	1Q 1994	1Q 1995	2Q 1994	2Q 2000	16,000	16,132
FY 1998 Budget Request	1Q 1994	1Q 1995	2Q 1994	2Q 2001	16,000	16,132
FY 2000 Budget Request *(Current Baseline Estimate)*	1Q 1994	1Q 1995	2Q 1994	2Q 2001	16,000	16,132

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Design and Construction			
FY 1993	4,024	0 [a]	0
FY 1994	3,300	3,136 [b]	75
FY 1995	3,000	197 [c]	2,463
FY 1996	2,089	2,089	1,431
FY 1997	0	0	918
FY 1998	3,987	3,921 [d]	2,324
FY 1999	4,908	4,908	4,200
FY 2000	1,749	1,749	3,820
FY 2001	0	0	769

a This project was proposed as an FY 1993 new start (93-E-329). Application of a portion (-$4,024,000) of the FY 1993 programmatic general reduction of $40,000,000 necessitated a delay in the start of this project to FY 1994.

b Reflects reductions as follows: $-68,000 Contractor Salary Freeze; $-96,000 rescission.

c Reflects application of a portion ($-2,803,000) of Energy Supply Research and Development reductions.

d Reflects application of a portion ($66,000) of Science general reduction.

3. Project Description, Justification and Scope

This project will replace deteriorated roofing on buildings and facilities throughout the Oak Ridge National Laboratory complex. ORNL has over 2.4 million square feet of roof area on approximately 160 buildings. Based on a recent study by the laboratory's Plant and Equipment Division, approximately seventy percent of the total area needs to be replaced due to age and deterioration. This project is the first of several planned projects to replace the deteriorated roofing. It will replace the roofs that are in the worst condition (top priority) on buildings housing the most important facilities. Most of the existing roofing materials contain asbestos and much of it has traces of radioactive contaminants. This project will provide for the installation of new roofing and includes the necessary engineered controls to assure compliance with applicable health and safety regulations.

Approximately 70 percent of the roofs have been in service for over 20 years. Because of age and deterioration, many of these roofs have already developed leaks and require an increasing amount of maintenance. The results of the Plant and Equipment Division study of these roofs, giving the type and condition of each roof by building, including conditions of asbestos and/or radioactive contamination, were used as the basis of the conceptual design. In some cases the problems have reached the point that they could affect equipment, records, and research activities, as well as the health and safety of personnel working in the buildings or facilities.

During the past few years budget constraints and the increased cost of satisfying environment, safety and health regulations have resulted in a reduction in funds available for roof replacement. The effects of this shortfall have been compounded by the increased cost associated with restrictions placed on work with or around asbestos materials. Most of the roofs needing replacement involve asbestos materials. This combination of factors has resulted in a growing backlog of roofs that need replacement due to a lack of adequate funding. The current average annual cost of roof repairs is $800,000. This does not include damage from leaks before repairs are made. There is currently a backlog of over $5,000,000 of repairs needed. The roof replacement program is normally funded from expense funds; however, line item funding is requested because of the magnitude of the backlog and the need to provide an acceptable margin of response to meeting future replacement needs in a timely manner.

Failure to fund this project will result in a continuation of the expensive piece-meal repair program. As the roofs age, the number of leaks will increase, repairs will become more expensive and the potential for serious structural and equipment damage will grow, along with the threat to employee health and safety. Further deterioration of facilities could result in decreased program funding for DOE and ORNL.

Use of the metric system of measurement for design, procurement and construction of this project was considered; but because of the nature of the work and the prevailing practices in the region, it was determined to be uneconomical.

4. Details of Cost Estimate [a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Engineering design inspection and administration of construction costs		
Engineering, design and inspection at approximately 7% of construction costs	800	800
Construction management at approximately 12% of construction costs	1,300	1,300
Project management costs at approximately 2% of engineering, design and inspection costs and construction management costs	200	200
Total, Engineering design inspection and administration of construction costs	2,300	2,300
Construction Costs (install new roofing) [b]	2,860	2,860
Removal and packaging of existing roofing	8,040	8,040
Design and project liason, testing, checkout and acceptance	200	200
Total, Construction Costs	13,400	13,400
Contingencies at approximately 19 percent of above costs	2,600	2,600
Total line item cost (TEC)	16,000	16,000

5. Method of Performance

Design shall be performed under a negotiated architect-engineer contract and inspection shall be performed by the operating contractor. To the extent feasible, construction and procurement shall be accomplished by fixed-price contracts and subcontracts awarded on the basis of competitive bidding.

a The cost estimate is based on conceptual design completed April 1991 at a cost of $70,000 and updated March 1993. The DOE Headquarters Economic Escalation Indices for Construction Projects were used as appropriate over the project cycle.

b Construction costs include $60,000 for readiness reviews.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Years	FY 1998	FY 1999	FY 2000	Outyears	Total
Project cost						
Facility Cost						
Line Item TEC	4,887	2,324	4,200	3,820	769	16,000
Other Project Costs						
Conceptual design cost	70	0	0	0	0	70
Site characterization	7	0	0	0	0	7
NEPA documentation	5	0	0	0	0	5
Other project-related costs	50	0	0	0	0	50
Total, Other project costs	132	0	0	0	0	132
Total Project Cost (TPC)	5,019	2,324	4,200	3,820	769	16,132

7. Related Annual Funding Requirements

(dollars in thousands)

	Current Estimate	Previous Estimate
Facility maintenance and repair costs [a]	515	515
Total related annual funding	515	515
Total operating costs (from FY 2001 through FY 2021)	515	515

[a] Includes dollars to repair roofing installed by this project over the estimated 20 years of life.

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, 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*. Participate 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

Energy Research Analyses

- Independent peer reviews verified the quality and relevance of over 100 DOE projects and tasks in FY 1997. These levels of effort will be scaled down through FY 2000 to accommodate the reduced funding.

- A new Office of Science Strategic Plan will be completed in FY 1999 that will guide the Office of Science into the first quarter of the next century.

- A Department of Energy Science Facilities Roadmap will be completed in FY 1999 that will optimize the Nation's investments in the Department's scientific facilities into the first quarter of the next century.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Energy Research Analyses					
Energy Research Analyses	1,434	1,000	0	1,000	1,000
Use of Prior Year Balances	-144 [1]	-92 [a]	0	-92 [a]	0
Total, Energy Research Analyses	1,290 [2]	908	0	908	1,000

Funding by Site

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Oak Ridge Operations Office					
Oak Ridge National Laboratory	665	400	400	0	0.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	100	0	0	0	0.0%
Richland Operations Office					
Pacific Northwest National Laboratory	0	350	250	-100	-28.6%
All Other Sites [3]	669	250	350	+100	+40.0%
Subtotal, Energy Research Analyses	1,434	1,000	1,000	0	0.0%
Use of Prior Year Balances	-144[a]	-92 [a]	0	+92 [a]	+100.0%
Total, Energy Research Analyses	1,290	908	1,000	+92	+10.1%

Public Law Authorization:

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

[1] 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.

[2] Excludes $36,000 which has been transferred to the SBIR program and $2,000 which has been transferred to the STTR program.

[3] Funding provided to laboratories, universities, industry, other Federal agencies and other miscellaneous contractors.

Site Description

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.

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.

All Other Sites

This line includes funding of 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 1998	FY 1999	FY 2000	$ Change	% Change
Energy Research Analyses	1,434	973	973	0	0.0%
SBIR/STTR	0	27	27	0	0.0%
Total, Energy Research Analyses	1,434	1,000	1,000	0	0.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
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.	1,434	973	973
SBIR/STTR			
■ In FY 1998, $36,000 and $2,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.	0	27	27
Total, Energy Research Analyses	1,434	1,000	1,000

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ There are no funding changes from FY 1999 to FY 2000 for Energy Research Analyses.	0
Total Funding Change, Energy Research Analyses	0

Fusion Energy Sciences

Program Mission

The Fusion Energy Sciences program is a broad-based, fundamental research effort, producing valuable scientific knowledge and technological benefits in the near term with the aim of providing the science base for a fusion energy option in the long term.

This is a time of important progress and discovery in fusion research. By virtue of previous investments in facilities, and more recently, sophisticated diagnostics and modeling capabilities, the Fusion Energy Sciences program is making great progress in understanding the fundamental processes of confining fusion fuels, such as the mechanisms responsible for turbulent losses of particles and energy across the magnetic field lines. In addition, the program is identifying and exploring innovative approaches to fusion power in search of an optimized confinement system with an affordable development path.

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

The goal of the Fusion Energy Sciences program is to:

> *"Acquire the knowledge base for an economically and environmentally attractive fusion energy source."*

Although there is not a schedule for developing and deploying fusion energy systems the availability of fusion, as an option for large central station power plants, would be valuable insurance against possible environmental concerns about fossil and nuclear energy. In addition, there may be nearer term non-electric applications of fusion in transmutation of wastes and isotope production.

Program Objectives

Crosscutting and interrelated objectives of the Fusion Energy Sciences program, as developed through stakeholder meetings and endorsed by the Fusion Energy Sciences Advisory Committee, are summarized below.

- *Understand the physics of plasmas, the fourth state of matter*. Plasmas comprise most of the visible universe, both stellar and interstellar, and have many practical applications. Progress in plasma physics has been the prime engine driving progress in fusion research, and conversely, fusion energy has been the dominant motivation for plasma physics research.
- *Identify and explore innovative and cost-effective development paths to fusion energy*. There are several approaches to fusion, from the tokamak, which is the most advanced power plant candidate, to alternative magnetic configurations, or to inertial confinement using particle beams or lasers. The

current fusion program includes research on tokamak improvements and, increasingly, research on other innovative concepts, including drivers for inertial fusion energy.

- *Explore the science and technology of energy producing plasmas, the next frontier in fusion research, as a partner in an international effort*. Understanding the physics of energy-producing (i.e. burning), plasmas and developing the technologies essential for fusion energy are linked goals that can best be achieved through the cooperative efforts of the world community. The long-term benefits to the United States in such a cooperative effort include enhanced progress toward our mission through scientific and technological integration in the much larger world fusion effort as an energy source for a growing world population.

The Fusion Energy Sciences budget is divided into three subprograms; Science, Facility Operations, and Enabling R&D. The Science subprogram includes research funds for plasma science and the development of improved confinement concepts. Funds for building and operating major experimental facilities are in the Facility Operations subprogram. The Enabling R&D subprogram includes funds for establishing the scientific foundation which underlies current advances in fusion technology and provides technological capabilities and innovations needed to advance plasma science and develop the knowledge base for an attractive fusion energy source.

Scientific Facilities Utilization

The Fusion Energy Sciences request includes $96,600,000 to maintain support of the Department's scientific user facilities. This investment will provide significant research time for thousands of 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 three major fusion energy physics facilities: the Doublet III-D at General Atomics, the Alcator C-Mod at the Massachusetts Institute of Technology and the National Spherical Torus Experiment at 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) human resource management. The ways in which the Fusion Energy Sciences program measures performance include components such as peer review, specific charges to the Fusion Energy Sciences Advisory Committee (FESAC), and professional recognition of research performers. These have been an integral part of the program for many years. Each major research facility has a Program Advisory Committee (PAC) that provides broadly based community input directly to the facility team. Proposals for new facilities or upgrades to existing facilities at laboratories have both scientific and cost and schedule reviews.

For FY 2000, specific performance measures are:

- The National Spherical Torus Experiment (NSTX) will operate with a National Research Team demonstrating long pulse (greater than 1 second) operation at plasma currents approaching 1 megampere, a factor of 40 increase over the current exploratory level spherical torus experiments.
- Three new innovative concept exploration experiments--the LSX field-reversed configuration, the flow-stabilized Z pinch (both at the University of Washington) and the Pegasus spherical torus at the University of Wisconsin--will be fully operational providing basic scientific understanding of relevant concept phenomena.
- The DIII-D tokamak will test the feasibility of using increased electron cyclotron heating power and improved power exhaust techniques to extend the pulse length of advanced toroidal operating modes, a necessary requirement for future fusion energy sources.
- A decontamination and decommissioning contract at the Princeton Plasma Physics Laboratory (PPPL) will be awarded for the removal of the Tokamak Fusion Test Reactor (TFTR) tokamak and activated components from the experimental test cell.
- The materials research program will be coordinated with design studies through an overall systems approach, and broadened to allow increased modeling and innovative exploratory research on novel materials" as recommended by the FY 1998 FESAC materials review.
- New funding opportunities in basic plasma science and junior plasma physics faculty development programs will be provided through competitive announcements.
- The theory of strong turbulence will be used as a foundation to develop models for using shear in the plasma flow to stabilize the transport of energy and particles in toroidal devices such as tokamaks and stellarators. In addition, a new energy transport code framework, based on modern computing techniques, will be completed and made available for use via the web.

Significant Accomplishments and Program Shifts

Science

- To accommodate continuing governmental financial constraints, the fusion sciences program continues to move toward more innovation and increased understanding of a wider range of confinement concepts, and away from the more costly, large scale devices aimed at providing integrated plasma and technology experiments operating with power plant-scale plasma parameters.
  - Support of the goal to understand the physics of plasmas continues at the increased level of funding for general plasma science to improve the basis for fusion science and research on high-temperature toroidal plasmas in the DIII-D, C-MOD, and NSTX experiments.
  - Support of the goal to explore innovative and more affordable development paths includes increased operation of the new NSTX science facility. Work on concept improvement at the exploratory level in both physics and enabling R&D will continue to receive strong emphasis.
- A major review of magnetic and inertial fusion energy options by the Secretary of Energy Advisory Board has begun in FY 1999 in response to congressional requests.

- The National Academy Review of the Quality of Science in the Fusion Energy Sciences Program will be carried out in FY 1999 as part of a follow-up to the 1996 restructuring of the fusion program.
- A review of leading candidates for the next proof-of-principle steps within the innovative confinement concepts program was carried out, and program recommendations will be made by FESAC in FY 1999.
- In FY 1999 scientists at the University of Wisconsin will begin testing new stellarator symmetry principles which promise to improve understanding of how to optimize this toroidal fusion concept. At the Lawrence Livermore National Laboratory the first experiments on high temperature sustainment of spheromak plasmas will begin. Both of these elements represent initial results from the FY 1996 restructuring of the fusion program to work more on innovative confinement concepts.
- Within the NSF/DOE Partnership in Basic Plasma Science and Engineering begun in FY 1997, an additional set of applications were reviewed in FY 1998, and 13 were selected for funding including two NSF Career awards. Of the successful applicants, 7 were funded directly by OFES and funding was shared for one of the NSF Career awards. The fusion-sponsored development program for junior faculty in plasma physics in FY 1998 resulted in 2 additional awards. Both programs will continue in FY 1999 and planning with other agencies, including NSF, will be carried out for FY 2000 initiatives.
- A peer-reviewed competition for new ideas in measurement techniques for toroidal and burning plasma devices was carried out in early FY 1999 and awards were announced in February 1999.
- The Electron-Impact Ionization Theory, which was developed at the National Institute of Standards and Technology for fusion applications, is beginning to find application in modeling for air pollution control devices and ionization and radiation monitors. Its application to modeling for plasma processing of semiconducting devices by INTEL and other companies, which was reported last year, continues to grow.
- Current drive using new microwave hardware was shown for high magnetic field operation of the Alcator C-Mod facility. These results, along with demonstrated microwave heating at high magnetic field, indicate that advanced toroidal operating modes can be produced and studied in Alcator C-Mod.

Facility Operations

- The National Spherical Torus Experimental (NSTX) project at the Princeton Plasma Physics Laboratory (PPPL) will be completed in FY 1999 and a national research team will be organized. The facility will begin experimental operations by the 3rd quarter of FY 1999 and the NSTX Program Advisory Committee (PAC) will provide guidance to PPPL for initial operations.
- Significant modifications to the divertor and heating systems of the DIII-D facility were completed, providing capabilities required for FY 2000 experiments that will extend the pulse duration of advanced toroidal operating modes. Important experimental results were obtained that show plasma stability control with feedback coils and demonstration of radio frequency current drive that is necessary for long pulse operations.

Enabling R&D

- Support of the goal to explore the science and technology of energy producing plasmas is dramatically reduced by termination in FY 1999 of U.S. participation in the international pursuit of leading edge science in an integrated, large-scale experimental facility (ITER).
- In early FY 1999, the U.S. will close out its participation in ITER design activities.
- In FY 1999, we will work with other ITER Parties to attempt to complete the testing of the ITER superconducting model coil in Japan. This testing program will confirm the design and establish operating margins and will allow us to benefit from the $45,000,000 we have invested in building a major portion of the coil.
- The fusion program will continue its bilateral and multilateral activities on major scientific facilities abroad and maintain observer contact with the ITER project to keep informed of progress by the remaining three ITER parties.
- The program will retain low activation materials research. However, remaining enabling R&D activities supporting energy-producing plasmas will be drastically reduced.
- A series of critical enabling R&D tasks involving radio-frequency heating and current drive components were successfully completed over the past year. Tasks include fabrication of the NSTX antenna and tuning system, and installation of a DIII-D high power microwave system. The results of these auxiliary heating development efforts will have broad applicability to future U.S. fusion experiments.
- AWARDS

  Marshall Rosenbluth, University of California at San Diego, was awarded the **National Medal of Science** in December 1997

  Darin Ernst, Princeton Plasma Physics Laboratory, won the **1998 APS-DPP Award for Outstanding Doctoral Dissertation in Plasma Physics**

  Nine fusion researchers were elected **Fellows of the American Physical Society in 1998**

  Paul Woskov, 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.

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 $115,000 and $96,000 for estimated contractor security clearances in FY 1999 and FY 2000, respectively, within this decision unit.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Fusion Energy Sciences					
Science	95,116	118,982	-664	118,318	125,434
Facility Operations	56,149	61,195	0	61,195	69,380
Enabling R&D	66,025	43,123	0	43,123	27,800
Program Direction	6,900	0	0	0	0
Subtotal, Fusion Energy Sciences	224,190	223,300	-664	222,636	222,614
General Reduction	0	-664	+664	0	0
Use of Prior Year Balances	-791 [a]	-1,136 [b]	0	-1,136 [b]	0
Total, Fusion Energy Sciences	223,399 [c]	221,500	0	221,500	222,614

Public Law Authorization:

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

[a] Share of Energy Supply, Research and Development general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] 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.

[c] Excludes $5,157,000 which has been transferred to the SBIR program and $309,000 which has been transferred to the STTR program.

Funding by Site

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	4,143	4,219	4,419	+200	+4.7%
Sandia National Laboratories	5,850	4,115	3,565	-550	-13.4%
Total, Albuquerque Operations Office	9,993	8,334	7,984	-350	-4.2%
Chicago Operations Office					
Argonne National Laboratory	2,835	2,540	2,135	-405	-15.9%
Brookhaven National Laboratory	50	0	0	0	0.0%
Princeton Plasma Physics Laboratory	49,612	50,332	58,979	+8,647	+17.2%
Total, Chicago Operations Office	52,497	52,872	61,114	+8,242	+15.6%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	4,120	1,740	1,000	-740	-42.5%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	3,947	5,334	5,255	-79	-1.5%
Lawrence Livermore National Laboratory . . .	10,518	11,158	10,168	-990	-8.9%
Stanford Linear Accelerator Center	50	50	50	0	0.0%
Total, Oakland Operations Office	14,515	16,542	15,473	-1,069	-6.5%
Oak Ridge Operations Office					
Oak Ridge Institute for Science and Education	1,229	910	800	-110	-12.1%
Oak Ridge National Laboratory	17,870	17,480	15,866	-1,614	-9.2%
Total, Oak Ridge Operations Office	19,099	18,390	16,666	-1,724	-9.4%
Richland Operations Office					
Pacific Northwest National Laboratory	1,415	1,410	1,430	+20	+1.4%
Savannah River Operations					
Savannah River Tech Center	452	219	0	-219	-100.0%
All Other Sites [a]	122,099	123,129	118,947	-4,182	-3.4%
Subtotal, Fusion Energy Sciences	224,190	222,636	222,614	-22	0.0%
Use of Prior Year Balances	-791 [b]	-1,136 [c]	0	+1,136 [c]	+100.0%
Total, Fusion Energy Sciences	223,399	221,500	222,614	+1,114	+0.5%

[a] Funding provided to laboratories, universities, industry, other federal agencies, and other miscellaneous contractors.

[b] Share of Energy Supply, Research and Development general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[c] 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

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 ITER components, including blankets, tritium systems, and plasma-facing components, as well as to analysis supporting 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 which 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 2000, fusion efforts at INEEL will be focused solely on safety research associated with existing or planned domestic experimental 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. The U.S. Heavy-Ion Fusion (HIF), centered at LBNL, program 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 will start 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 2000 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 Magnetic Target Fusion, and maintenance of the Tritium Systems Test Assembly (TSTA) facility in a standby mode.

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 Office of Fusion Energy Sciences (OFES), ORISE acts as an independent and unbiased agent to administer the Fusion Energy Sciences Graduate and Postgraduate Fellowship Programs, in conjunction with OFES, the Oak Ridge Operations Office (ORO), participating universities, DOE laboratories, and industries. ORISE also assists in the organization and administrative support for the Fusion Energy Sciences Advisory Committee meetings.

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. ORNL will provide leadership of the Virtual Laboratory for Technology, which integrates all U.S. fusion program enabling R&D activities into a coordinated multi-institutional framework. 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 particles. Research is also done in the area of turbulence and its effect on transport of heat through 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.

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 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 interfaces of plasmas and fusion device first wall. 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 in use in fusion devices. Materials samples and prototypes are tested in Sandia's Plasma Materials Test Facility, which use high-power electron beams to stimulate 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 51 colleges/universities located in 25 states. This line also includes funding for DIII-D and related programs at General Atomics and funding of research awaiting distribution pending completion of review results or program office detailed planning.

Science

Mission Supporting Goals and Objectives

The goals of this subprogram are to advance our understanding of plasma science, 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 both toroidal innovations and in non-toroidal concepts; focused efforts to resolve outstanding physics issues related to energy producing plasmas; strong theory and modeling programs; and the creation of improved diagnostics that make possible rigorous testing of the scientific principles of fusion.

Plasma science is the study of ionized matter—ranging from neon lights to stars—that make up 99 percent of the visible universe. It contributes not only to fusion research, but also to many national science and technology goals, ranging from astrophysics to industrial processing to national security. One objective of the Science subprogram is to broaden the intellectual and institutional base in fundamental plasma physics. Ongoing programs including a development program for junior faculty in plasma physics and a joint NSF/DOE partnership in plasma physics and engineering contribute to this objective.

Fusion energy research advances through a balanced combination of large-, medium-, and small-scale experiments, theory, and modeling. The largest component of the Science subprogram is the tokamak research activity, which focuses on gaining a predictive understanding of the behavior of plasmas in near reactor-level conditions where the fusion fuel begins to "burn". Tokamak research will be carried out primarily on the DIII-D facility at General Atomics. DIII-D has been a major contributor to the world fusion program over the past decade by developing advanced modes of toroidal operations through the flexibility of its plasma shaping and computer control systems, and by increasing the knowledge base of fusion physics through extensive diagnostics and theoretical and modeling support of experiments. The other major U.S. tokamak experiment, the Alcator C-Mod at the Massachusetts Institute of Technology (MIT), uses high magnetic fields to explore high temperature and density plasmas in a unique, compact, and cost-effective facility. Additional high-leverage tokamak research will be carried out through international collaborations on large, state-of-the-art facilities abroad. Increased collaboration on facilities such as JET (Europe) and JT-60 (Japan) was recommended by the Fusion Energy Science Advisory Committee.

Research on alternative confinement concepts, both magnetic and inertial, is aimed at identifying approaches that may improve the economical and environmental attractiveness of fusion energy sources. This research is carried out at various levels ranging from the concept explorations stage to the proof-of-principle stage. The first proof-of-principle experiment, the new National Spherical Torus Experiment (NSTX) facility at the Princeton Plasma Physics Laboratory (PPPL), will begin its first full year of operation in FY 2000, with a goal of demonstrating improved stability and confinement in a very compact structure over the next several years. Additional proof-of-principle level experiments at PPPL, University of Wisconsin, and Los Alamos National Laboratory have been positively reviewed and are awaiting further consideration by the Fusion Energy Sciences Advisory Committee. Small-scale exploratory experiments are carried out primarily at universities, while proof-of-principle experiments, such as the NSTX will be primarily hosted at national laboratories.

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 developing the components needed to apply the ICF results to energy systems. These include the most efficient methods for heating and compressing a target pellet to fusion conditions, methods for clearing the target chamber between pulses, and target design.

Theory and modeling are essential to progress in fusion and plasma science because they 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 computational tools to help understand the physical phenomena that govern confinement of high temperature plasmas. Similarly, the development and improvement of diagnostic tools for analyzing plasma behavior continues to provide new insights regarding fusion plasmas.

Performance Measures

- Three new innovative concept exploration experiments--the LSX field-reversed configuration, the flow-stabilized Z pinch (both at the University of Washington) and the Pegasus spherical torus at the University of Wisconsin--will be fully operational providing basic scientific understanding of relevant concept phenomena.
- A new energy transport code framework, based on modern computing techniques, will be completed and made available for use via the web.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Tokamak Experimental Research	46,198	46,831	45,918	-913	-1.9%
Alternative Concept Experimental Research	23,996	38,600	45,150	+6,550	+17.0%
Theory	19,773	22,500	23,000	+500	+2.2%
General Plasma Science	5,149	6,109	6,500	+391	+6.4%
SBIR/STTR	0	4,278	4,866	+588	+13.7%
Total, Science	95,116	118,318	125,434	+7,116	+6.0%

Detailed Program Justification

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
Tokamak Experimental Research			
■ TFTR physics research was completed in 1998.	5,500	0	0
■ DIII-D at General Atomics (GA) is the major operating tokamak in the United States. DIII-D is a national facility, with about half of its scientific staff coming from U.S. fusion laboratories other than GA, as well as some from several foreign laboratories. In FY 2000 the research activity will focus on use of two new hardware improvements in auxiliary heating and power exhaust systems. This will allow progress in the development of advanced toroidal operations for long pulses which is essential for incorporation of these operating modes into the design of future machines.	21,430	21,905	22,520
■ Alcator C-Mod will also operate as a national facility with an improved set of diagnostics. Research activity will focus on support of the compact, high field approach to ignition and on the physics of the plasma edge and power exhaust.	6,211	7,600	7,800
■ 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. 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. The requested funding level in FY 2000 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.	6,557	7,400	7,250

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ International collaboration at the level of $4,200,000 provides the opportunity for joint and coordinated experiments between the U.S. and foreign experiments, thereby increasing the database and the understanding of fusion physics. With the limited operation of major tokamaks in the U.S., international collaboration provides increased opportunity for the U.S. scientists to continue their participation in the advancement of fusion science, especially in the area of burning plasma physics. The scientists from PPPL and ORNL will continue collaborations with JET, Tore Supra, TEXTOR, and ASDEX-UG in Europe and with JT-60U in Japan. The remaining $4,148,000 is required for graduate and postgraduate fellowships in fusion science and technology, 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. . . .	6,500	9,926	8,348
Total, Tokamak Experimental Research	46,198	46,831	45,918

Alternative Concept Experimental Research

■ **Experimental Plasma Research (Alternates):** Research on novel magnetic confinement configurations is important both for its intrinsic scientific value and for its potential to discover concepts that would make more attractive fusion power sources. This category has two components. The first component contains twelve diversified exploratory level experiments located primarily in universities. Four of these experiments (Sustained Spheromak Physics Experiment at LLNL; Columbia University/MIT Dipole; Ion Rings at Cornell University; and Ion Trap at LANL) resulted from a FY 1998 innovative concept competition. A second category includes design and experimental work on three novel concepts that have been proposed for full proof-of-principle funding..	14,550	19,000	23,750

■ **NSTX:** The NSTX at PPPL will begin the first full year of research in FY 2000. The research program will be organized as a national collaboration with representatives of other institutions participating in the research activity on an equal basis with researchers from PPPL. Initial objectives will be plasma formation, two methods of controlled startup, plasma heating by radio-frequency waves and diagnostic surveys to define acceptable operational regimes that can be used

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
for more powerful experiments. Advanced diagnostic development specifically for NSTX is also funded by this element.	2,446	9,800	11,300
■ **Inertial Fusion Energy:** Inertial fusion energy research continues with efforts to improve heavy ion accelerator efficiency, chamber wall protection, and design of fusion energy target pellets. Scoping studies for major next step device options will be undertaken, with a goal of providing the inertial fusion energy program the capacity to benefit from physics results on Defense Programs' National Ignition Facility in the latter part of the next decade.	7,000	9,800	10,100
Total, Alternative Concept Experimental Research	23,996	38,600	45,150

Theory

- The theory and modeling program is a broad-based program with researchers located at national laboratories, universities, and industry. A new program emphasis is advanced computing, including the development of new modeling codes and a code library for use by all fusion researchers. Work in tokamak theory ($15,105,000) includes efforts to support existing toroidal experiments and also includes the development of many new theories and modeling tools, since these are usually applied to tokamaks before being applied to alternates. An example of this is work on self organized criticality, which may provide a new approach to understanding confinement. The majority of the work in toroidal theory is aimed at developing a complete physical picture of advanced toroidal operating modes. With the restructuring of the fusion program, there is an increased focus on alternate concepts. In alternate concept theory ($2,707,000), the emphasis will be on understanding the fundamental processes determining equilibrium, stability, and confinement in each alternate. Generic theory ($2,188,000) covers development of basic plasma theory that is applicable not only to fusion research, but also to basic plasma science. It also includes work on atomic theory, which is applicable to all confinement devices.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
The objective of the advanced computing activity is to improve simulation 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 2000, funds ($3,000,000) will be used to develop a modern transport code to simulate energy transport in toroidal magnetic confinement systems. . .	19,773	22,500	23,000
General Plasma Science			
■ The plasma science program focuses on basic plasma science and engineering research, primarily in the university community. Advances in basic plasma physics will support the Fusion Energy Sciences program as well as other important areas of science and technology. Both the Plasma Science Junior Faculty Development Program and collaborative efforts such as the NSF/DOE plasma science and engineering program will continue at FY 1999 levels. The program will also continue to collect and distribute atomic physics data for fusion.	5,149	6,109	6,500
SBIR/STTR			
■ In FY 1998 $3,476,000 and $208,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	4,278	4,866
Total, Science	95,116	118,318	125,434

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Tokamak Experimental Research	
■ Additional funding is provided for increased diagnostics on DIII-D.	+615
■ Additional funding is provided for increased research expenses on Alcator C-Mod..	+200

	FY 2000 vs. FY 1999 ($000)
■ This decrease is primarily associated with the FY 1999 prior year general reduction account going to zero in FY 2000.	-1,578
■ Reduction will decrease support for research at UCLA	-150
Total, Tokamak Experimental Research	-913
Alternative Concept Experimental Research	
■ Support for NSTX research is increased to provide funding for personnel and minor equipment for the first full year of operations that includes research collaborations and preparations of advanced diagnostics.	+1,500
■ Funding for alternate concept experiments is increased to maintain breadth and permit establishment of one or more proof-of-principle experiments..	+4,750
■ This increase will permit continued efforts to improve accelerator efficiency for inertial fusion energy..	+300
Total, Alternative Concept Experimental Research	+6,550
Theory	
■ The advanced computational effort will expand efforts to develop new codes to predict plasma performance.	+500
General Plasma Science	
■ These funds will enhance the NSF/DOE Partnership in Basic Plasma Science and Engineering.	+391
SBIR/STTR	
■ Support for SBIR/STTR is mandated at 2.65 percent. These grants will support plasma science, fusion science, and fusion enabling R&D.	+588
Total Funding Change, Science	+7,116

Facility Operations

Mission Supporting Goals and Objectives

This activity provides for the operation of major experimental facilities that are the essential tools that enable scientists in university, industry, and laboratory based research groups to perform experimental research in fusion research facilities: DIII-D at GA, Alcator C-Mod at MIT, and NSTX at PPPL. These 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. It includes the cost of operating personnel, electric power, expendable supplies, replacement parts and subsystems, and inventories. In the case of PPPL, this funding also supports beginning the final three-year phase of decontamination and decommissioning of the Tokamak Fusion Test Reactor which was shut down in FY 1997; ongoing caretaking for the tritium systems and activated elements is required during this process. General plant projects (GPP) funding for PPPL supports minor facility renovations, other capital alterations and additions, and buildings and utility systems. Capital equipment funding for upgrading the research capability of DIII-D is also included, as are funds for design, modification, and installation of the NSTX neutral beam heating system, and for further enhancements to the facility.

The principal objective of the Facility Operations subprogram is to maximize the quantity and quality of data collected for experiments being conducted at fusion energy science facilities.

The following table summarizes the scheduled weeks of operations for DIII-D and NSTX.

Facility Utilization

(Weeks of Operation)

	FY 1998	FY 1999	FY 2000
DIII-D	15	14	14
Alcator C-Mod	9	12	18
TFTR	8	0 [a]	0 [a]
NSTX	0	6	14

[a] Facility Shutdown.

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
TFTR	5,140	3,600	13,600	+10,000	+277.8%
DIII-D	26,370	29,195	29,880	+685	+2.3%
Alcator C-Mod	9,689	9,923	10,100	+177	+1.8%
NSTX	13,850	16,800	15,000	-1,800	-10.7%
General Plant Projects /Other	1,100	1,677	800	-877	-52.3%
Total, Facility Operations	56,149	61,195	69,380	+8,185	+13.4%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
TFTR			
■ Begin a three-year program ($10,000,000 in FY 2000 out of a planned total of $48,000,000) to complete the decontamination and decommissioning of TFTR. This activity will provide for the removal and disposal of the tokamak and remaining activated components from the test cell and the basement. In addition during the D&D funding ($3,600,000) is necessary to maintain and keep the facility safe during the project.	5,140	3,600	13,600
DIII-D			
■ Provides support for operation, maintenance, and improvement of the DIII-D Electron Cyclotron Heating (ECH) systems and support for other equipment at the GA site. In FY 2000, these funds support plasma operation using hydrogen and deuterium fuel for approximately 14 weeks; plus downtime for significant upgrades to the ECH, divertor systems, and maintenance.	26,370	29,195	29,880
Alcator C-Mod			
■ Provides support for operation, maintenance and minor machine improvements. In FY 2000, these funds support plasma operation using hydrogen and deuterium fuel for approximately 18 weeks; plus down time for machine and diagnostic improvements.	9,689	9,923	10,100

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
NSTX			
■ Provides for continuation of research activity on the NSTX experiment and installation of the first set of planned diagnostic upgrades. This will allow extension of the pulse duration to 1 second and operation at plasma currents approaching 1 megampere, a factor of 40 increases over current exploratory level spherical torus experiments; first investigations of non-inductive current drive, a principal program objective; and measurement of advanced plasma confinement scenarios.	1,770	7,900	12,500
■ **NSTX Project:** Project completed in FY 1999 and facility begins operations.	12,080	5,450	0
■ **NSTX Neutral Beam:** Project for preparation and installation of a previous TFTR neutral beam heating system on NSTX.	0	3,450	2,500
Total, NSTX	13,850	16,800	15,000
General Plant Projects/Other			
■ These funds provide primarily for general infrastructure repairs and upgrades. The major project included in the FY 2000 plan is an upgrade of the fire alarm system throughout the site where NSTX is located.	1,100	1,677	800
Total, Facility Operations	56,149	61,195	69,380

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
TFTR	
■ Funding is provided to initiate TFTR decontamination and decommissioning.	+10,000
DIII-D	
■ Additional funding is for operation of increased number of DIII-D systems (ECH, divertor, etc.).	+685
Alcator C-Mod	
■ Additional funding is provided for increased operation of the Alcator C-Mod.	+177
NSTX	
■ A decrease for the NSTX project at PPPL is due to the completion of fabrication, and a shift to facility operations.	-5,450
■ An increase in NSTX facility operations to support the first full year of operations.	+4,600
■ A decrease in NSTX neutral beam heating system to complete this fabrication effort.	-950
Total, NSTX	-1,800
General Plant Projects/Other	
■ General Plant Projects support at PPPL is increased $100,000 to reflect maintenance requirements; support for other facility operations is terminated.	-877
Total Funding Change, Facility Operations	+8,185

Enabling R&D

Mission Supporting Goals and Objectives

For sustained scientific 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 technology innovations. The Enabling R&D subprogram includes funds for: (1) establishing the scientific foundation that underlies current technological advances in fusion, and (2) providing the technological capabilities and innovations needed to advance fusion science; developing the knowledge base for an attractive fusion energy source. These contribute to two strategic goals for the fusion program. This subprogram is divided into two elements: Engineering Research and Materials Research.

For the Engineering Research element, activities through FY 1998 were heavily oriented toward the ITER Engineering Design Activities (EDA), a four party (European Union, Japan, Russian, U.S.) international effort to demonstrate the scientific and technological feasibility of fusion as an energy source. In July 1998 the other three ITER parties prepared to enter into a 3-year post-EDA extension period that would develop a reduced cost design and provide the basis for an assessment of the technical, financial, and hosting readiness to proceed with ITER construction as an international project. However the DOE was unable to obtain congressional agreement for U.S. participation in the extension. Accordingly, the U.S. effort toward ITER will be closed out in early FY 1999, and the Engineering Research element restructured by being downsized and redirected away from energy-oriented goals.

In restructuring this element in FY 1999, the scope of activities will be broadened to address more fully the diversity of domestic interests in enabling R&D. These interests include a focus on critical needs for enabling technologies for U.S. plasma experiments and for international collaborations that allow the U.S. to access plasma experimental conditions not available domestically. These interests also include the scientific foundations of innovative technology concepts for future plasma experiments. These innovations are needed to exploit the performance gains being sought from physics concept improvement research. Major FY 1998 accomplishments include: completion, as an ITER participant, of the ITER Final Design Report, which is the first comprehensive, fully integrated design of a major fusion power experiment; completion of winding the ITER superconducting magnet model coil, which will be shipped to Japan in early FY 1999 for testing in a Japanese facility during FY 1999; and completion of critical tasks involving radio-frequency heating and plasma current drive components that have broad applicability to the U.S. fusion program.

The Materials Research element continues to focus its scientific research on low-activation materials which have high performance capability and can withstand long-term exposure to the energetic particles and electromagnetic radiation expected from energy-producing plasmas. During FY 1998, this element made major inroads toward mapping of irradiation effects on candidate low-activation alloys, which is needed to set priorities for future research, and underwent a review by FESAC that will continue to influence planning for FY 1999 and beyond.

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Engineering Research	58,281	34,991	20,074	-14,917	-42.6%
Materials Research	7,744	7,000	7,000	0	0.0%
SBIR/STTR	0	1,132	726	-406	-35.9%
Total, Enabling R&D	66,025	43,123	27,800	-15,323	-35.5%

Detailed Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Engineering Research			
■ Funding reductions will require a substantial downsizing and redirection of effort on the energy-oriented technology segment of the fusion program. Efforts will be focused on critical needs of domestic plasma experiments and on the scientific foundations of innovative technology concepts for future plasma experiments. Nearer-term experiment support efforts will be oriented toward plasma facing components ($5,600,000) and plasma heating and fueling technologies ($3,700,000). Longer-term efforts will be oriented toward: superconducting magnet research ($1,500,000) and plasma facing and energy extraction component innovations ($1,500,000) needed to fully exploit investments in concept improvement experiments; and toward tritium research ($1,000,000) and safety research ($1,000,000) issues critical to the safety and environmental attractiveness of fusion as an energy source. Advanced design studies will be directed toward identifying attractive pathways toward fusion energy ($2,950,000). In addition, design studies of next-step options ($2,224,000), taking fullest advantage of recent scientific advances, will continue. Management of this diverse collection of fusion technologies will be accomplished through a Virtual Laboratory for Technology ($600,000) whereby improved coordination and communication of plans, progress, and results will be accomplished through the use of modern information technology.	58,281	34,991	20,074

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
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.	7,744	7,000	7,000
SBIR/STTR			
■ In FY 1998 $1,681,000 and $101,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	1,132	726
Total, Enabling R&D	66,025	43,123	27,800

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Engineering Research	
■ Reduction in research on superconducting magnets plasma facing components and plasma fueling (following completion of ITER Superconducting Model Coil)..	-7,322
■ Reduction in research on energy extraction, diagnostics, tritium processing, vacuum vessel welding, remote handling, and safety.	-2,731
■ Reduction in design of next step option experiments being considered within U.S. domestic fusion program.	-1,276
■ Increase in Advanced Design Studies	+500
■ Reduction in information technology research	-948
■ Reduction in ITER closeout costs to zero in FY 2000	-3,140
Total, Engineering Research	-14,917

	FY 2000 vs. FY 1999 ($000)
SBIR/STTR	
■ Reduction due to overall reduction in Engineering Research.	-406
Total Funding Change, Enabling R&D	-15,323

Program Direction

Mission Supporting Goals and Objectives

This subprogram was transferred to the Science Program Direction decision unit in FY 1999 at the direction of Congress. This subprogram provided the Federal staffing resources and associated funding needed to plan, direct, manage, and administer the highly complex scientific and technical research and development program in fusion energy.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	910	0	0	0	0.0%
Travel	74	0	0	0	0.0%
Support Services	0	0	0	0	0.0%
Other Related Expenses	190	0	0	0	0.0%
Total, Chicago Operations Office	1,174	0	0	0	0.0%
Full Time Equivalents	11	0	0	0	0.0%
Oakland Operations Office					
Salaries and Benefits	184	0	0	0	0.0%
Travel	14	0	0	0	0.0%
Support Services	0	0	0	0	0.0%
Other Related Expenses	2	0	0	0	0.0%
Total, Oakland Operations Office	200	0	0	0	0.0%
Full Time Equivalents	2	0	0	0	0.0%
Headquarters					
Salaries and Benefits	4,001	0	0	0	0.0%
Travel	225	0	0	0	0.0%
Support Services	600	0	0	0	0.0%
Other Related Expenses	700	0	0	0	0.0%
Total, Headquarters	5,526	0	0	0	0.0%
Full Time Equivalents	39	0	0	0	0.0%

(dollars in thousands, whole FTEs)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Total Fusion Energy Sciences					
Salaries and Benefits	5,095	0	0	0	0.0%
Travel	313	0	0	0	0.0%
Support Services	600	0	0	0	0.0%
Other Related Expenses	892	0	0	0	0.0%
Total, Program Direction	6,900	0	0	0	0.0%
Full Time Equivalents	52	0	0	0	0.0%

Detailed Program Justification

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
Salaries and Benefits			
■ Funded staff managing and supporting the Fusion Energy Sciences program.	5,095	0	0
Travel			
■ Provided on-site contractor and facility oversite and participated in major scientific conferences to maintain state-of-the-art scientific and technical expertise.	313	0	0
Support Services			
■ Provided the level of support services needed to provide for the program's mailroom; security; travel services; information technology, infrastructure; and environment, safety and health support..	600	0	0
Other Related Expenses			
■ Provided funds to cover the minimum level of funds to cover hardware/software acquisitions, infrastructure technology upgrades, training, special emphasis programs and the Working Capital Fund..	892	0	0
Total, Program Direction	6,900	0	0

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ This subprogram was transferred to the Science Program Direction decision unit in FY 1999 at the direction of Congress.	N/A

Support Services

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Technical Support Services					
Feasibility of Design Considerations	0	0	0	0	0.0%
Economic and Environmental Analysis	0	0	0	0	0.0%
Test and Evaluation Studies	0	0	0	0	0.0%
Total, Technical Support Services	0	0	0	0	0.0%
Management Support Services					
Management Studies	0	0	0	0	0.0%
Training and Education	5	0	0	0	0.0%
ADP Support	245	0	0	0	0.0%
Administrative Support Services	350	0	0	0	0.0%
Total, Management Support Services	600	0	0	0	0.0%
Total, Support Services	600	0	0	0	0.0%

Other Related Expenses

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Training	0	0	0	0	0.0%
Working Capital Fund	500	0	0	0	0.0%
Printing and Reproduction	0	0	0	0	0.0%
Rental Space	26	0	0	0	0.0%
Software Procurement/Maintenance Activities/Capital Acquisitions	366	0	0	0	0.0%
Total, Other Related Expenses	892	0	0	0	0.0%

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
General Plant Projects	1,100	700	800	+100	+14.3%
Capital Equipment	15,295	16,645	10,810	-5,835	-35.1%
Total, Capital Operating Expenses	16,395	17,345	11,610	-5,735	-33.1%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 1998	FY 1999	FY 2000	Accept-ance Date
DIII-D Upgrade	32,400	18,225	1,550	5,440	5,440	FY 2002
NSTX	21,100	3,570	12,080	5,450	0	FY 1999
NSTX - Neutral Beam	5,950	0	0	3,450	2,500	FY 2000
Total, Major Items of Equipment		21,795	13,630	14,340	7,940	

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; and supporting university and science education. 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 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.

Also included in Program Direction are several specific education related activities. For over 50 years, the Department of Energy and its predecessor agencies (Atomic Energy Commission and the Energy Research and Development Administration) has 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 the Energy Department’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 key to the Department’s contribution over time to the Nation’s science and engineering education goals.

The funds appropriated for science education will support activities that utilize the Department’s scientific and technical resources to enhance the development of a diverse, well-educated and scientifically literate workforce.

In addition to the science education program in this science program direction budget, other mission oriented education activities are funded within science research programs. Below is a table identifying the programs and the allocation of funds. The funds will allow university faculty and student teams at the undergraduate level to participate on long-term research projects at DOE laboratories. Pre-college science and math teachers will be provided with research appointments to improve their knowledge and skills of scientific discovery and enhance their ability to apply them in a classroom environment. Through these investments, the Department will make major contributions towards fulfilling several national priorities: enhancing the diversity of the technical workforce; supporting systemic reform of undergraduate education; and attracting, retaining, and graduating students in fields of interest to DOE and others in the public and private sectors. The funds will also allow the Department to encourage educators to participate directly in the ongoing science research of its laboratories. By joining teams of researchers, educators will experience directly the cutting-edge development of the Science Laboratories, and will better understand the process of scientific investigation. Funds provided will pay for faculty/student and pre-college teachers' stipends, travel, and housing and will subsidize laboratory scientists' time for this activity.

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Basic Energy Sciences	0	0	1,947
Computational Technology Research	0	0	1,947
Biological and Environmental Research	0	0	1,947
High Energy Physics	0	0	2,921
Nuclear Physics	0	0	973
Total	0	0	9,735

Program Goal

To fund the staff and related expenses that are necessary to provide overall management direction of SC's basic and fundamental scientific research programs funded in the Science appropriation; and to enable the Director of SC to serve as the Department's science advisor for formulation and implementation of basic and fundamental research policy.

For science education the goal is to ensure that the Department effectively utilizes and leverages the resources of its laboratory-based system to support its energy, science and math education mission.

Program Objectives

- To develop, direct and administer a complex and broadly diversified program of mission-oriented basic and applied research and development designed to support the development of 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 to leverage the U.S. investment in research and development.
- To review, analyze and, where appropriate, champion the recommendations of the Office of Science'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, and Biological and Environmental Research Advisory Committee.
- To provide opportunities and effective mechanisms for students and faculty to participate at the Department's laboratories in hands-on research experiences, with a focus on undergraduates.
- To enhance departmental outreach activities in science, technology, engineering and mathematics education at our R&D facilities in order to increase the awareness and understanding of the general public of the Department's science programs.

Performance Measures

- Responsiveness to national science policy and major science initiatives.
- Improvement in environment, safety and health compliance.
- Provision for new and enhanced research facilities and equipment within scope and budget and on schedule.
- Continued improvement in the utilization of staffing, travel and support contractor funds.
- Continuance of improved levels of facility operating time.
- Expansion of international collaborative efforts.
- Cost sharing and leveraging of program resources with other agencies on a one-to-one basis to multiply the program's impact.
- Increase the flow of underrepresented students up to 50 percent into science and math programs/careers achieved.

Significant Accomplishments and Program Shifts

Program Direction

- The Office of Science 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 support contractor staff compared to other programs both within and outside the Department.
- Increased productivity at U.S. scientific research facilities as part of the Scientific Facilities Utilization initiative.

- 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 program has begun.
- Initiated operation of the William R. Wiley Environmental Molecular Sciences Laboratory at Pacific Northwest National Laboratory.
- At Fermilab, complete construction of the C-Zero Experimental Hall within scope and budget, and on schedule (FY 1999 completion); and complete the Main Injector within scope and budget, and on schedule (FY 1999 initial operation).
- Complete the B-factory and its detector at the Stanford Linear Accelerator Center within scope and budget, and on schedule (FY 1999 initial operation).
- Continue construction of the Relativistic Heavy Ion Collider and its detectors at Brookhaven National Laboratory within scope and budget, and on schedule (FY 2000 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.
- Carrying out experiments at the Radioactive Ion Beam facility at Oak Ridge National Laboratory.
- Continue pilots in FY 1999 for transfer of management responsibility from Environmental Management to Science for newly generated wastes at the Stanford Linear Accelerator Center (SLAC) and Fermilab.
- Manage the Joint Genome Institute and the Atmospheric Radiation Measurement sites using the National Laboratories as an integrated system.
- Strengthen integrated safety 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 science.
- Continue and refine framework of appropriate international arrangements needed to carry out SC programs in a most cost-effective manner.
- Continue to improve environmental, safety and health performance at the Brookhaven National Laboratory through aggressive implementation of the DOE Action Plan for Improved Management of the Laboratory.
- 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 (NuMI) project.

- Establishment of the Spallation Neutron Source Project Office at the Oak Ridge Operations Office in FY 2000.
- Implement the Scientific Simulation Initiative to rapidly develop and deploy a national terascale computing infrastructure and apply it to complex civilian science and engineering problems of national importance.

Science Education

- The Science 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 Science Undergraduate Laboratory Research Fellowship Program has attracted a diverse group of students using the electronic application. Nearly 20 percent of those submitting applications represented under represented ethnic groups. About 40 percent of the applications were female, and more than 25 percent were from low-income families. More than 400 summer 1998 appointments were made through the new application process with additional appointments expected in the fall.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Science Program Direction					
Program Direction	37,600	45,300	0	45,300	47,860
Science Education	0	4,500	0	4,500	4,500
Total, Science Program Direction	37,600 [a]	49,800	0	49,800	52,360
Staffing (FTEs)					
Headquarters (FTEs)	220	269	0	269	274
Field (FTEs)	34	49	0	49	51
Total, FTEs	254 [a]	318	0	318	325

Public Law Authorization:

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

[a] In FY 1998 $6,900,000 was appropriated for 52 FTEs in the Energy Supply Research and Development Fusion Energy Sciences program now funded in Science Program Direction.

Funding by Site

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Chicago Operations Office					
Ames Laboratory	0	250	250	0	0.0%
Argonne National Laboratory	0	525	525	0	0.0%
Brookhaven National Laboratory	0	525	525	0	0.0%
Fermi Nat'l Accel. Laboratory	0	225	225	0	0.0%
Princeton Plasma Physics Laboratory	0	275	275	0	0.0%
Total, Chicago Operations Office	0	1,800	1,800	0	0.0%
Golden Field Office					
Nat'l Renewable Energy Laboratory	0	225	225	0	0.0%
Oakland Operations Office					
Lawrence Berkeley Nat'l Laboratory	0	475	475	0	0.0%
Stanford Linear Accel. Center	0	225	225	0	0.0%
Total, Oakland Operations Office	0	700	700	0	0.0%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science & Education	0	400	400	0	0.0%
Oak Ridge Nat'l Laboratory	0	475	475	0	0.0%
Thomas Jeff. Nat'l Accel. Facility	0	225	225	0	0.0%
Total, Oak Ridge Operations Office	0	1,100	1,100	0	0.0%
Richland Operations Office					
Pacific Northwest Nat'l Laboratory	0	475	475	0	0.0%
All Other Sites	37,600	45,500	48,060	+2,560	+5.6%
Total	37,600	49,800	52,360	+2,560	+5.1%

Site Description

Ames Laboratory

Ames Laboratory is a Multiprogram Laboratory located on 10 acres in Ames, Iowa. 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. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

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. 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. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Brookhaven National Laboratory

Brookhaven National Laboratory is a Multiprogram 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. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Fermi National Accelerator Laboratory

Fermi National Accelerator Laboratory is a program-dedicated laboratory (High Energy Physics) located on a 6,000 acre site in Batavia, Illinois. 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. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

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. 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. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

National Renewable Energy Laboratory

National Renewable Energy Laboratory is a program-dedicated laboratory (Solar) located on 300 acres in Golden, Colorado. 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. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Oak Ridge National Laboratory

Oak Ridge National Laboratory is a Multiprogram 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. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

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. Educational activities are in support of the national laboratory participation program which provides 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.

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. 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. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

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. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

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. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

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. Teachers, utilizing the Department's extensive computational and communications technology expertise, will also concentrate on developing tools and materials to translate their research experiences into computerized learning tools that can be used to take advantage of the universal availability of the Internet as a teaching medium.

Program Direction

Mission Supporting Goals and Objectives

Program Direction provides the Federal staffing resources and associated costs required to provide overall direction and execution of Office of Science program and advisory responsibilities. Science 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. This program also supports staff at the Chicago, Oakland, and Oak Ridge Operations Offices directly involved in program execution. 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, and environment, safety and health.

The FY 2000 request includes Working Capital Fund resources of $3,285,000 to cover the costs of centrally provided goods and services at Headquarters, such as supplies, rent, and utilities.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	1,949	3,054	3,345	+291	+9.5%
Travel	93	187	190	+3	+1.6%
Support Services	5	198	160	-38	-19.2%
Other Related Expenses	84	124	166	+42	+33.9%
Total, Chicago Operations Office	2,131	3,563	3,861	+298	+8.4%
Full-Time Equivalents	20	32	32	0	0.0%
Oakland Operations Office					
Salaries and Benefits	695	867	889	+22	+2.5%
Travel	20	51	51	0	0.0%
Support Services	0	0	0	0	0.0%
Other Related Expenses	35	39	39	0	0.0%
Total, Oakland Operations Office	750	957	979	+22	+2.3%
Full-Time Equivalents	6	10	10	0	0.0%

(dollars in thousands, whole FTEs)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Oak Ridge Operations Office					
Salaries and Benefits	633	634	833	+199	+31.4%
Travel	35	40	70	+30	+75.0%
Support Services	0	0	52	+52	+100.0%
Other Related Expenses	32	68	117	+49	+72.1%
Total, Oak Ridge Operations Office	700	742	1,072	+330	+44.5%
Full-Time Equivalents	8	7	9	+2	+28.6%
Headquarters					
Salaries and Benefits	23,343	28,409	30,180	+1,771	+6.2%
Travel	1,015	1,240	1,420	+180	+14.5%
Support Services	4,690	5,146	5,120	-26	-0.5%
Other Related Expenses	4,971	5,243	5,228	-15	-0.3%
Total, Headquarters	34,019	40,038	41,948	+1,910	+4.8%
Full-Time Equivalents	220	269	274	+5	+1.9%
Total Science					
Salaries and Benefits	26,620	32,964	35,247	+2,283	+6.9%
Travel	1,163	1,518	1,731	+213	+14.0%
Support Services	4,695	5,344	5,332	-12	-0.2%
Other Related Expenses	5,122	5,474	5,550	+76	+1.4%
Total, Science Program Direction	37,600	45,300	47,860	+2,560	+5.7%
Full-Time Equivalents	254	318	325	+7	+2.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Salaries and Benefits			
Staff funded in this decision unit monitor and evaluate over 3,500 grants and contracts at more than 225 institutions, including universities, industry and other government agencies, in addition to monitoring and evaluating the programs at 13 National and single-purpose Laboratories. SC also manages the Department-wide Small Business Innovation Research and Small Business Technology Transfer programs. Our reengineering efforts have eliminated unnecessary and non-value added work from the system where possible. In FY 2000, SC will also support the Spallation Neutron Source Project Office in Oak Ridge and the Scientific Simulation Initiative.	26,620	32,964	35,247
Travel			
The FY 2000 estimate reflects escalation of costs for airfare, lodging, etc. This increase only reflects a two percent increase over FY 1999. Alternatives to travel such as teleconferencing will be utilized when possible.	1,163	1,518	1,731
Support Services			
Provide necessary mailroom, travel services, environment, health and safety support, computer systems development, SBIR program support, security and hardware and software installation, configuration, and maintenance activities. Emphasis in FY 1999 and FY 2000 will be placed on continued implementation of an information architecture for Science to establish integrated business management systems, consistent with the provisions of the Clinger-Cohen Act (Information Technology Management Reform Act) of 1996. This is essential to take work out of the system and to meet workload demands. SC is widely acknowledged as being the most efficient and conservative user of support services contracts in the Department.	4,695	5,344	5,332

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
Other Related Expenses			
Acquire computer hardware and software in FY 1999 and FY 2000 necessary to accomplish corporate systems development and networking upgrades. The FY 1999 and FY 2000 estimates include $3,243,000 and $3,285,000, respectively, to cover Headquarters Working Capital Fund charges.	5,122	5,474	5,550
Total, Program Direction	37,600	45,300	47,860

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Salaries and Benefits	
■ Increase of $2,283,000 in salaries and benefits is due to two additional FTE's for the Spallation Neutron Source Project Office in Oak Ridge, five additional FTEs for the Scientific Simulation Initiative, and the impact of cost of living, locality pay, within grades, promotions, lump sum payments, and awards.	+2,283
Travel	
■ Increase of $213,000 in travel provides a partial offset for escalation of travel costs, airfare, lodging, and miscellaneous expenses due to inflation	+213
Support Services	
■ Decrease of $12,000 in support services provides the minimum level of support services needed to provide for SC's needs.	-12
Other Related Expenses	
■ Increase of $76,000 in Other Related Expenses provides the minimum amount of funds to cover hardware/software acquisitions, infrastructure technology upgrades, field training, and the Working Capital Fund.	+76
Total Funding Change, Science Program Direction	+2,560

Support Services

(dollars in thousands)	FY 1998	FY 1999	FY 2000	$ Change	% Change
Technical Support Services					
Economic and Environmental Analysis	1,488	1,488	1,325	-163	-11.0%
Test and Evaluation Studies	0	160	100	-60	-37.5%
Total, Technical Support Services	1,488	1,648	1,425	-223	-13.5%
Management Support Services					
Management Studies	207	207	110	-97	-46.9%
Training and Education	58	63	40	-23	-36.5%
ADP Support	2,282	2,376	2,847	+471	19.8%
Administrative Support Services	660	1,050	910	-140	-13.3%
Total, Management Support Services	3,207	3,696	3,907	+211	5.7%
Total, Support Services	4,695	5,344	5,332	-12	-0.2%

Other Related Expenses

(dollars in thousands)	FY 1998	FY 1999	FY 2000	$ Change	% Change
Training	60	71	76	+5	7.0%
Working Capital Fund	2,679	3,243	3,285	+42	1.3%
Printing and Reproduction	0	33	11	-22	-66.7%
Rental Space	0	26	0	-26	-100.0%
Software Procurement/Maintenance Activities/Capital Acquisitions	2,383	2,101	2,172	+71	3.4%
Other	0	0	6	+6	+100.0%
Total, Other Related Expenses	5,122	5,474	5,550	+76	1.4%

Science Education

Mission Supporting Goals and Objectives

For over 50 years, the Department of Energy and its predecessor agencies (the Atomic Energy Commission and the Energy Research and Development Administration) has 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 the Energy Department'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 the recruitment and retention into science and engineering of students who have historically been under represented (e.g., women, disabled persons, African Americans, Hispanic Americans and Native Americans) in these fields. Guided by recent reports such as the National Research Council on Undergraduate Education Achievement Trends in Science and Engineering, the Department will continue to design, through the Office of Science, 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 underrepresented 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.

In addition to the science education program in this science program direction budget, $9,734,000 of other mission oriented education activities are funded within science research programs. Below is a table identifying these programs and the allocation of funds. The funds will allow university faculty and student teams at the undergraduate level to participate on long-term research projects at DOE laboratories. Pre-college science and math teachers will be provided with research appointments to improve their knowledge and skills of scientific discovery and enhance their ability to apply them in a classroom environment. Through these investments, the Department will make major contributions towards fulfilling several national priorities: enhancing the diversity of the technical workforce; supporting systemic reform of undergraduate education; and attracting, retaining, and graduating students in fields of interest to DOE and others in the public and private sectors. The funds will also allow the Department to encourage educators to participate directly in the ongoing science research of its laboratories. By joining teams of researchers, educators will experience directly the cutting-edge development of the Science Laboratories, and will better understand the process of scientific investigation. Funds provided will pay for faculty/student and pre-college teachers' stipends, travel, and housing and will subsidize laboratory scientists' time for this activity.

(dollars in thousands)	FY 1998	FY 1999	FY 2000
Basic Energy Sciences	0	0	1,947
Computational Technology Research	0	0	1,947
Biological and Environmental Research	0	0	1,947
High Energy Physics	0	0	2,921
Nuclear Physics	0	0	973
Total	0	0	9,735

Funding Schedule

(dollars in thousands)	FY 1998	FY 1999	FY 2000	$ Change	% Change
Undergraduate SC Laboratory Fellowship Program	0	3,900	3,900	0	0.0%
National Science Bowl Program	0	400	400	0	0.0%
Albert Einstein Distinguished Educator Fellowship Program	0	200	200	0	0.0%
Total, Science Education	0	4,500	4,500	0	0.0%

Detailed Program Justification

(dollars in thousands)	FY 1998	FY 1999	FY 2000
Undergraduate SC Laboratory Fellowship Program			
The Science Undergraduate Laboratory Research Fellowship Program is a key component of the SC Science Education Program to enable 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. The program will also ensure a steady flow of students with technical expertise into the Nation's pipeline of workers in both academia and industry.	0	3,900	3,900

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
National Science Bowl Program In addition, the Office of Science will manage and support the "National Science Bowl" for high school students from across the country. Since its inception, more than 50,000 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 who have prepared them a forum to receive national recognition for their talent and hard work. We are planning to invest $400,000 into the National Science Bowl to manage both regional and national competitions.	0	400	400
Albert Einstein Distinguished Educator Fellowship Program The Albert Einstein Fellowship Awards for High School 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 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. We plan to invest $200,000 in the Einstein Fellowship Awards which will allow us to place teachers at the Department and in the U.S. Congress.	0	200	200
Total, Science Education	0	4,500	4,500

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ No funding changes from FY 1999 to FY 2000 for Science Education.	0
Total Funding Change, Science Education	0