Corporate Context for
Science (SC) Programs

This section on Corporate Context that is included for the first time in the Department's budget is provided to facilitate the integration of the FY 2003 budget and performance measures. The Department's Strategic Plan published in September 2000 is no longer relevant since it does not reflect the priorities laid out in President Bush's Management Agenda, the 2001 National Energy Policy, OMB's R&D project investment criteria or the new policies that will be developed to address an ever evolving and challenging terrorism threat. The Department has initiated the development of a new Strategic Plan due for publication in September 2002, however that process is just beginning. To maintain continuity of our approach that links program strategic performance goals and annual targets to higher level Departmental goals and Strategic Objectives, the Department has developed a revised set of Strategic Objectives in the structure of the September 2000 Strategic Plan.

For the past 50 years, U.S. taxpayers have earned an enormous return on their investment in the basic research sponsored by the Department of Energy's Office of Science. The science underlying a multitude of discoveries – ranging from advanced energy and environmental technologies that reduce consumer electricity bills while protecting the environment, to great leaps in our knowledge of how the universe originated – has flowed out of the national laboratories and universities where DOE-sponsored scientists conduct their research. During Fiscal Year 2003, DOE will continue this legacy of discovery through strategic investments in basic research and the major national scientific user facilities that the Office of Science builds and operates on behalf of the Nation.

The events of 2001, particularly the war on terrorism, underscore the continuing need for sustained investments in basic research. DOE's accomplishment of its missions in national security, energy, and environment rely upon advances in basic research that are managed by the Office of Science. This basic research – which encompasses such diverse fields as materials sciences, chemistry, high energy and nuclear physics, plasma science, plant sciences, biology, advanced computation, and environmental studies – is contributing to effective counter measures in the war on terrorism, the Administration's goal of U.S. energy independence, and the overall vitality of the U.S. science and technology enterprise.

Science (SC) Goal

Deliver the scientific knowledge and discoveries for DOE's applied missions; advance the frontiers of the physical sciences and areas of the biological, environmental and computational sciences; and provide world-class research facilities and essential scientific human capital to the Nation's overall science enterprise.

Strategic Objectives

SC1: Determine whether the Standard Model accurately predicts the mechanism that breaks the symmetry between natural forces and generates mass for all fundamental particles by 2010 or whether an alternate theory is required, and on the same timescale determine whether the absence of antimatter in the universe can be explained by known physics phenomena. (HEP)

SC2: By 2015, describe the properties of the nucleon and light nuclei in terms of the properties and interactions of the underlying quarks and gluons; by 2010, establish whether a quark-gluon plasma can be created in the laboratory and, if so, characterize its properties; by 2020, characterize the structure and reactions of nuclei at the limits of stability and develop the theoretical models to describe their properties, and characterize using experiments in the laboratory the nuclear processes within stars and supernovae that are needed to provide an understanding of nucleosynthesis. (NP)

SC3: By 2010, develop the basis for biotechnology solutions for clean energy, carbon sequestration, environmental cleanup, and bioterrorism detection and defeat by characterizing the multiprotein complexes that carry out biology in cells and by determining how microbial communities work as a system; and determine the sensitivity of climate to different levels of greenhouse gases and aerosols in the atmosphere and the potential resulting consequences of climate change associated with these levels by resolving or reducing key uncertainties in model predictions of both climate change that would result from each level and the associated consequences. (BER)

SC4: Provide leading scientific research programs in materials sciences and engineering, chemical sciences, biosciences, and geosciences that underpin DOE missions and spur major advances in national security, environmental quality, and the production of safe, secure, efficient, and environmentally responsible systems of energy supply; as part of these programs, by 2010, establish a suite of Nanoscale Science Research Centers and a robust nanoscience research program, allowing the atom-by-atom design of revolutionary new materials for DOE mission applications; and restore U.S. preeminence in neutron scattering research and facilities. (BES)

SC5: Enable advances and discoveries in DOE science through world-class research in the distributed operation of high performance, scientific computing and network facilities; and to deliver, in 2006, a suite of specialized software tools for DOE scientific simulations that take full advantage of terascale computers and high speed networks. (ASCR)

SC-6: Advance the fundamental understanding of plasma, the fourth state of matter**,** and enhance predictive capabilities, through the comparison of well-diagnosed experiments, theory and simulation; for MFE, resolve outstanding scientific issues and establish reduced-cost paths to more attractive fusion energy systems by investigating a broad range of innovative magnetic confinement configurations; advance understanding and innovation in high-performance plasmas, optimizing for projected power-plant requirements; develop enabling technologies to advance fusion science, pursue innovative technologies and materials to improve the vision for fusion energy; and apply systems analysis to optimize fusion development; for IFE, leveraging from the ICF program sponsored by the National Nuclear Security Agency's Office of Defense Programs, advance the fundamental understanding and predictability of high energy density plasmas for IFE. (FES)

SC7: Provide major advanced scientific user facilities where scientific excellence is validated by external review; average operational downtime does not exceed 10% of schedule; construction and upgrades are within 10% of schedule and budget; and facility technology research and development programs meet their goals. (Crosscutting all major programs.)

SC8: Ensure efficient SC program management of research and construction projects through a re-engineering effort of SC processes by FY 2003 that will support world class science through systematic improvements in SC's laboratory physical infrastructure, security, and ES&H. (Covers the following accounts: Energy Research Analysis, Science Laboratories Infrastructure, Science Program Direction, Science Education, Field Operations, Safeguards and Security, Technical Information)

Office of Science

Executive Summary

The Office of Science (SC) requests $3,285,088,000 for the Fiscal Year 2003 Science appropriation, an increase of $4,349,000 over FY 2002, to conduct the basic research that underpins Department of Energy (DOE) applied technology programs; advance the frontiers of the physical sciences and areas of biological, environmental and computational sciences; and, provide world-class research facilities for the Nation's science enterprise. Setting aside funds for the Spallation Neutron Source and projects that required one-time funding in FY 2002, science funding increases by about 5 percent. For the Technical Information Management program in the Energy Supply appropriation, $8,353,000 is requested, an increase of $304,000 over FY 2002.

SC's FY 2003 investments in basic research respond to U.S. and DOE priorities in national defense, energy security and environmental quality. In addition, SC supports the U.S. science and technology base through investments in fundamental research, such as high energy and nuclear physics, and the construction and operation of major scientific facilities that are used annually by more than 17,000 researchers. The FY 2003 budget request for SC is compared to the FY 2002 Appropriation in Figure 1 below.

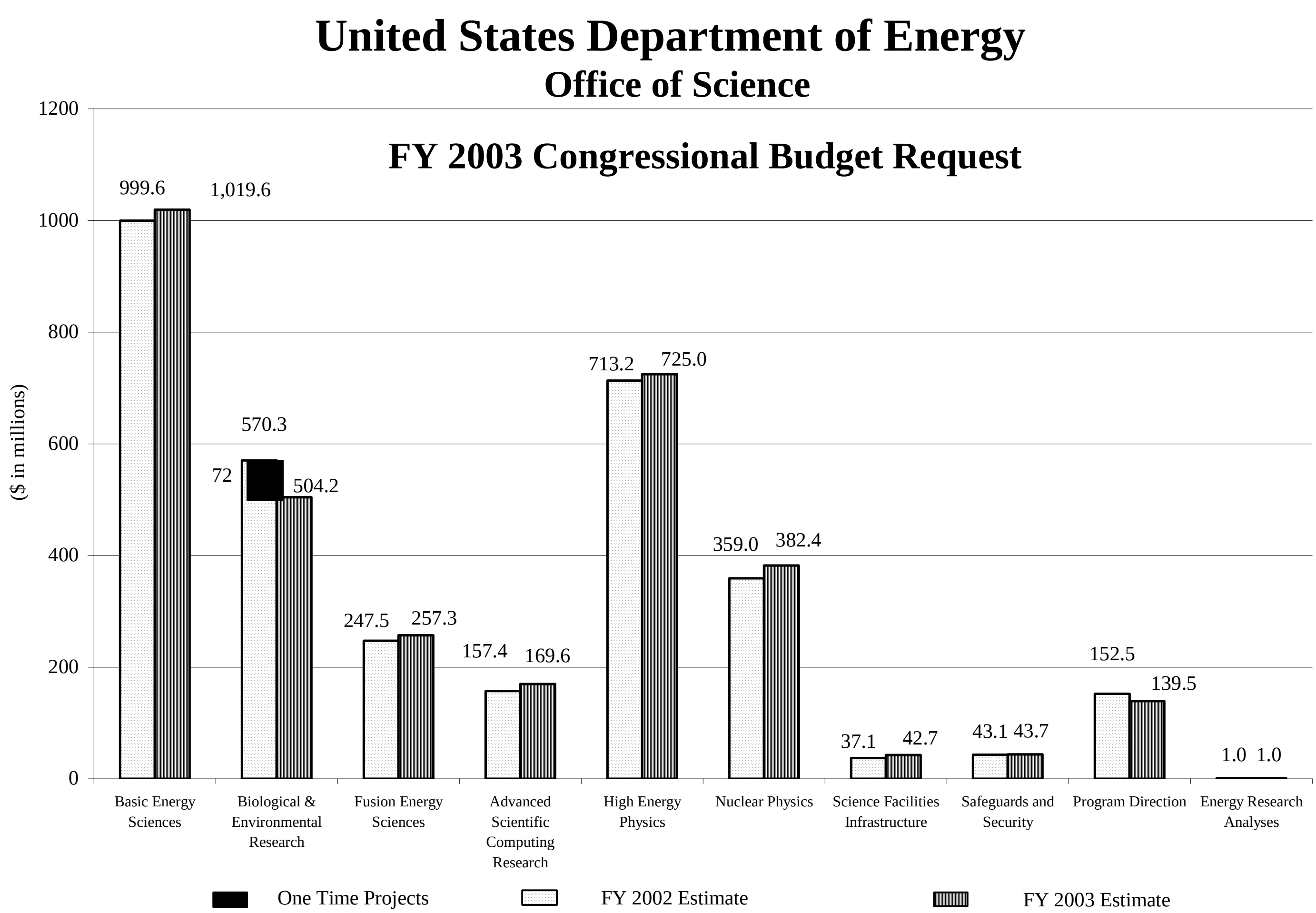


Figure 1

FY 2003 Priorities – Strategic Investments in Knowledge and Discovery

SC basic research underpins DOE's applied technology programs through strategic investments that fuel discoveries in materials sciences, chemistry, plasma science, plant sciences, biology, computation and environmental studies. In addition, SC sponsors leading edge research in physics and other areas that extend the frontiers of knowledge and discovery. Through these investments in basic research, SC is tackling some of the most challenging scientific questions of the 21st century.

SC researchers, for example, are manipulating the smallest components of matter to create the world's tiniest machines, which could lead to major advances in energy production, manufacturing processes, medical devices and computational capabilities; they are using decades of accumulated knowledge in the life sciences and advanced computation to fully understand a variety of biological processes to clean up the environment and defeat biological terrorism; and they are exploring the origins of mass, including searching for the mysterious and elusive "Higgs boson," (expected to be key to understanding mass) and ways to synthesize an extreme form of matter that existed for only a fraction of a second after the Big Bang.

Specifically, the FY 2003 request supports:

- ***Advanced scientific user facilities to accomplish vital DOE and national missions.*** SC will design, build, and operate scientific user facilities for university, laboratory, and industry researchers, providing U.S. scientists with the tools needed to secure our national defense, promote energy security, make advances in health, and increase U.S. technological competitiveness. During the next five years, SC will design and/or complete new research tools. Examples include the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory and NuMI at Fermilab. The U.S. will be restored to a position of leadership in neutron scattering research after the SNS becomes operational in FY 2006.

- ***Nanoscale science to make significant leaps in energy production and other DOE mission areas.*** SC will be part of a Federal government effort to establish international leadership in nanoscale science, enabling the atom-by-atom design of materials and integrated systems that will lead to important contributions to U.S. national security, energy production and environmental quality. Nanoscale science is the next major frontier in materials sciences, chemistry, biology, engineering, and a host of other scientific disciplines. Advancing basic knowledge in nanoscale science, and drawing on SC's unique core competencies and recognized interdisciplinary capabilities, will enable SC and its Federal partners (NSF, DoD, etc.) to secure international leadership in this emerging area of science.

- ***Genomes to Life in support of DOE missions in energy, national security, and environmental quality.*** Scientific breakthroughs and knowledge in gene function and protein structure that create new biological approaches will be used to address DOE's missions. This will be accomplished through an understanding of the genetic and environmental basis of normal and abnormal cell function, and the development of tools to understand gene function and protein structure needed for biotechnology solutions for clean energy, carbon sequestration, environmental cleanup, and bioterrorism detection and defeat.

- ***Climate Change Research.*** SC will contribute to the Administration's global climate change goals by resolving or reducing key uncertainties in predicting the effects of human activities on climate. SC will provide the foundation to predict, assess and mitigate potential adverse effects of energy production and use on the environment through research in climate modeling, climate processes, carbon cycle and carbon sequestration, atmospheric chemistry, and ecological science.

- ***Innovation in fusion/plasma science and technologies as part of the Administration's National Energy Policy.*** Fusion offers the potential for abundant, safe, environmentally attractive, affordable energy. Research in the science and the technology of fusion has progressed to the point that the next major step in the program is the exploration of the physics of a self-sustained fusion reaction, or a burning plasma physics experiment. SC will conduct research that supports such an experiment. In addition, SC will explore innovative approaches to confining, heating, and fueling plasmas.

- ***Fundamental research to resolve two key questions about the nature of matter and energy.*** SC is exploring two significant elements of the Standard Model, the current accepted theory of matter and energy, and it's validity in explaining the fundamental forces in the universe, including the complex interactions of energy, matter, time and space**.** SC's High Energy Physics (HEP) program has a unique opportunity during the next five years to make a key discovery that will help scientists worldwide understand the origin of mass in the universe, one of the great unsolved questions in physics. Until the Large Hadron Collider in Europe becomes operational sometime after 2005, the HEP program is the only one in the world with facilities capable of detecting the elusive Higgs Boson (expected to be key to understanding mass). Additionally, one of the persistent mysteries of modern physics is the general absence of observed anti-matter in the universe – a puzzle that HEP could resolve within the next five years by explaining the role of Charge-Parity (CP) violation.

- ***Attempts to synthesize an extreme form of matter that only existed for a fraction of a second at the Big Bang – the Quark-Gluon Plasma.*** The Nuclear Physics program is working to synthesize for the first time in a laboratory the extreme state of matter that existed microseconds after the Big Bang: a Quark-Gluon Plasma. This scientific achievement will reveal the nature and behavior of the most fundamental building blocks of matter. Now that SC's Relativistic Heavy Ion Collider (RHIC) facility is fully operational, intensive study is underway that could lead to the human-made creation and discovery of an extreme form of matter (Quark-Gluon Plasma) that existed just after the Big Bang at the start of the universe. This discovery would pave the road to a fuller understanding of our universe and how basic matter and energy processes can be explained.

- ***A new era of scientific discovery through advances in computation.*** SC initiated the Scientific Discovery through Advanced Computing (SciDAC) program to exploit advances in computing and information technologies as tools for scientific discovery across SC's research programs. SciDAC encourages and enables a new model of multi-discipline collaboration among the scientific disciplines, computer scientists and mathematicians to develop a new generation of scientific simulation codes that can fully exploit terascale computing and networking resources. SciDAC's goal is to bring simulation to a level of parity with experiment and theory in the scientific research enterprise as demonstrated by the production of breakthrough scientific results in climate prediction, plasma physics, particle physics, astrophysics and computational chemistry.

Science for DOE and the Nation

The importance of Federal support to the sciences was underscored by President Bush in an April 2001 speech to the high-tech industry:

> ***"Science and technology have never been more essential to the defense of the nation and the health of our economy."***
> **President George W. Bush**

SC is one of the primary government sponsors of basic research in the United States, and leads the Nation in supporting the physical sciences. SC's primary responsibility is to be an effective manager of scientific disciplines and scientific resources that are focused on vital DOE and national priorities. The President's affirmation of the importance of Federal investments in science and technology continues an unbroken line of support by our Nation's leaders for the sciences that stretches back 56 years – a line of support that parallels the history of SC and its predecessors.

In FY 2003 SC will continue its long history of effective project and program management to ensure that DOE and national missions are accomplished. SC's responsibilities as a manager of Federal science investments have resulted in the integration of the SC national laboratories into a system that contributes on a daily basis to our Nation's scientific and technological advances; support for world-class scientists at these laboratories and at U.S. research universities in the conduct of peer-reviewed and competitively selected research in areas of national priority; and the construction and operation of major scientific user facilities (such as high intensity X-ray sources and massively parallel computer centers) for the Nation's scientists. SC's basic research programs facilitate interactions among researchers in universities, industries, Federal laboratories, and the private sector to ensure that the full value of the Nation's research base is focused on meeting DOE's missions.

> *"Scientific progress is one key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress."*
>
> **Vannevar Bush, Science Advisor to President Truman, July 1945**

SC responsibilities on behalf of the Nation's scientific enterprise focus on four major areas:

- ***Advancing major national priorities***. SC's basic research programs have made major contributions to U.S. technological success in supercomputing, climate change science, and a host of other areas. In the energy arena, for example, SC researchers provided the scientific basis for rechargeable microbatteries, energy-efficient refrigeration, low-loss transformers, clean-burning engines, wear-resistant coatings, high-efficiency solar collectors and solar cells, high-temperature superconducting wires, solid state lasers, and intermetallic alloys. This record of success has been well documented and can be found on the Office of Science's web page at: http://www.sc.doe.gov/feature_articles_2001/June/Decades/

  Performance Indicator: Office of Science funded scientists are annually awarded major scientific prizes for their ground-breaking research. For example, SC and its predecessor agencies have funded the work of dozens of Nobel Laureates. Most recently, SC funded the work of the 1997 Chemistry Nobelist for work on the molecular mechanism underlying the synthesis of adenosine triphosphate (ATP), the most basic energy source within living systems.

  Performance Indicator: Office of Science research has led to some of the most important discoveries of our age, including discovery of the family of quarks that make up the atomic nucleus, verifying the existence of the "Third Branch of Life" (Archaea) in 1996, and playing a key role in the development of the draft human genome in 2000.

- ***Supporting key areas of basic research***, such as materials sciences, chemistry, physics, plasma science, plant sciences, biology, advanced computation, and environmental studies, which provide the scientific understanding that underpins DOE's applied technology programs in energy, national security, and the environment. In so doing, SC also contributes to our Nation's S&T infrastructure - which is the foundation of our high technology economy. Figure 2 depicts five fields of research for which DOE is among the top five sources of Federal support. This basic research enables major advances in energy efficiency, renewable energy resources, fossil fuels, reduced environmental impacts of energy production and use, science-based stockpile stewardship, and future energy sources.

FY 2001 Federal Research Funding*

Source: NSF *** dollars in thousands**

Life Sciences	Physical Sciences	Environmental Sciences	Mathematics and Computing	Engineering
1. HHS $14,313,905	1. **Energy** $1,843,445	1. NASA $1,060,705	1. **Energy** $886,382	1. NASA $2,240,332
2. USDA $1,340,895	2. NASA $943,617	2. NSF $626,202	2. DOD $744,773	2. DOD $2,065,123
3. DOD $534,489	3. NSF $668,502	3. Interior $386,758	3. NSF $490,552	3. **Energy** $1,192,198
4. VA $283,699	4. DOD $381,272	4. Commerce $328,088	4. HHS $158,418	4. NSF $574,836
5. **Energy** $274,126	5. HHS $245,695	5. **Energy** $311,523	5. NASA $88,744	5. Transportation $395,252

Figure 2

<u>*Performance Indicator:*</u> 96% of SC's research grants are peer reviewed and competitively selected, ensuring that the best research performers are chosen and that competition for Federal research dollars results in superior science.

<u>*Performance Indicator:*</u> SC regularly conducts major reviews of the programs and projects that it manages. These reviews ensure that the quality and relevance of science sponsored by SC meets the high standards needed to ensure that DOE and national mission requirements are achieved. For example, DOE and NSF jointly charged the High Energy Physics Advisory Panel to develop a long-range plan for the Nation's High Energy Physics program and their final report, submitted in January 2002, outlines a 20-year "roadmap" for the program. Also in early 2002, the nuclear physics community completed a new *Long Range Plan for Nuclear Physics*, outlining a 10-year plan for the Nation's Nuclear Physics program, in response to a charge by DOE and NSF to the Nuclear Science Advisory Committee.

- ***Constructing and managing major scientific facilities*** that the U.S. research community depends upon for new discoveries and technological advances. These unique scientific user facilities are essential to new understanding of the nature of matter, understanding fusion plasmas, the development of new drugs, lightweight materials, and other innovations that keep the U.S. at the forefront of new technologies.

<u>*Performance Indicator:*</u> SC's construction of major research facilities historically has been on time and on budget (Figure 3).

<u>*Performance Indicator:*</u> SC's operation of major scientific facilities has ensured that a growing number of U.S. scientists have reliable access to those important facilities. The number of users at major SC user facilities is projected to grow to over 17,000 in FY 2002 and over 18,000 in FY 2003 (Figure 4). Of particular note has been the growth in users at SC's light sources. Biologists and other life scientists

have been working cooperatively with physicists and other physical scientists in multi-disciplinary teams to achieve breakthroughs in medicine, biotechnology and other fields (Figure 5).

SC Research Facility
Major Construction Projects

Completed Projects[1]	Schedule	Cost	Date Completed
Continuous Electron Beam Accel. Facility (CEBAF)	✔	✔	4th Qtr 95
Advanced Photon Source (APS)	✔	✔	4th Qtr 96
Environmental Molecular Science Laboratory (EMSL)	✔	✔	4th Qtr 97
B-Factory	✔	✔	3rd Qtr 99
Fermilab Main Injector (FMI)	✔	✔	3rd Qtr 99
Relativistic Heavy Ion Collider (RHIC)	✔	✔	4th Qtr 99
On-Going Projects			
Neutrinos at the Main Injector (NuMI)[2]	✔	✔	4th Qtr 05
Large Hadron Collider (LHC)[3]	✔	✔	4th Qtr 05
Spallation Neutron Source (SNS)	✔	✔	3rd Qtr 06

[1]All completed projects were finished within scope

[2]NuMI: SC revised the cost/schedule baseline in FY 2002. The TPC increased to $171.4M.

[3]LHC: U.S. participation includes DOE ($450M) and NSF ($81M).

Figure 3

Performance Indicator: On average, SC ensures that operational downtime does not exceed 10% of the schedule at its major scientific user facilities. Consistent operating time is vital to the Nation's scientific community because scheduling of experiments often involves long lead times and teams of scientists often have only a narrow window of opportunity to conduct their work.

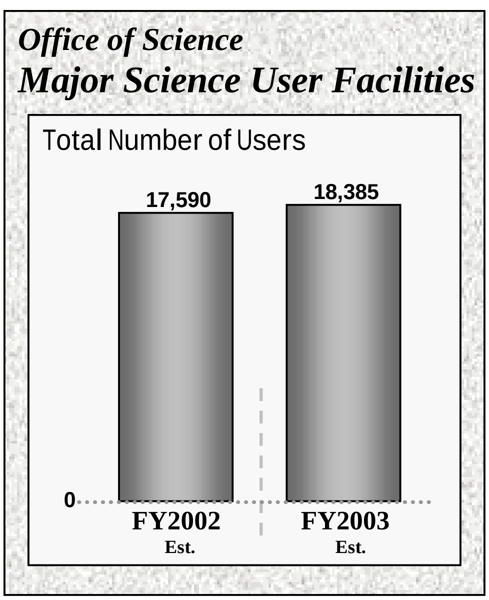


Figure 4

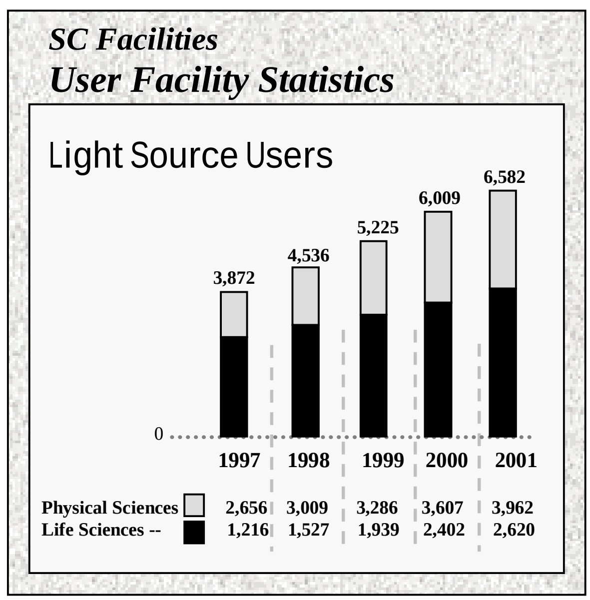


Figure 5

- ***Managing the human capital and physical resources*** that form the foundation for SC's basic research programs. SC has direct and indirect responsibility for the health and well-being of tens of thousands of national laboratory and university researchers who work at SC facilities, a highly skilled Federal workforce, and a network of national labs and facilities that have a replacement value in the multi-billions of dollars.

Major Program Activities for FY 2003

The **High Energy Physics** (HEP) program provides over 90% of the Federal support for the Nation's high energy physics research. This research seeks to understand the nature of matter and energy at the most fundamental level, as well as the basic forces that govern all processes in nature. High energy physics research requires accelerators and detectors utilizing state-of-the-art technologies in many areas including fast electronics, high speed computing, superconducting magnets, and high power radio-frequency devices. In these areas, HEP research has led to many developments with practical applications in the civilian marketplace as well as to widespread applications in other scientific disciplines. In addition, this program provides the basis for an excellent education for some of the brightest young minds in the Nation — a number of whom find employment in other scientific fields and private industry.

Until 2006, when Europe's Large Hadron Collider is scheduled to begin operations, the U.S. is the primary center for HEP research. Beginning in FY 2002, the Department's HEP program has focused its resources to take full advantage of this window of opportunity, particularly at Fermilab and the Stanford Linear Accelerator Center (SLAC). This focus continues in FY 2003. At Fermilab, following completion and successful commissioning of the Main Injector and major upgrades to the CDF and D-Zero detectors, the Tevatron Collider Run II began in March 2001. The Tevatron will be running fully in FY 2003 toward a goal of discovering the long-sought Higgs particle (thought key to understanding mass) and other important new physics.

Similarly at SLAC, there is a window of opportunity to take advantage of the outstanding performance of the B-factory to break new ground in exploring the source and nature of Charge-Parity (CP) violation in the B-meson system. For this reason, maximum running is planned for the B-factory in FY 2003. Upgrades are planned in FY 2003 for the accelerator to achieve optimal physics output and for the detector and computing capabilities to cope with high data volumes. In 2001, the BaBar detector collaboration achieved one of its physics milestones, announcing the first definitive measurement of CP violation in the B-meson system.

Although the Alternating Gradient Synchrotron (AGS) at Brookhaven is a Nuclear Physics facility, high priority HEP experimentation continued there through FY 2002. Due to a restructuring of priorities within the program, use of the AGS for HEP is terminated in FY 2003.

Support for university and laboratory based theory and experimental research, related to the high priority experiments at Fermilab and SLAC, will continue to be emphasized in FY 2003. These experimental programs are performed by university (primarily) and laboratory based scientists. These scientists construct, operate, and maintain the detectors, analyze the resulting data, and train the next generation of scientists.

Successful completion of construction and major capital equipment projects continues to be an important part of the program. Continued participation in the Large Hadron Collider (LHC) project at CERN is a high priority. The U.S. contributions to the LHC accelerator and the ATLAS and CMS detectors are making good progress and are on schedule and within budget for the current LHC scheduled start-up date of 2006. The NuMI/MINOS project, scheduled for completion in September 2005, will provide a world-class facility to study neutrino properties and make definitive measurements of neutrino mass differences.

Progress continues on two particle astrophysics experiments in partnership with NASA. The Alpha Magnetic Spectrometer (AMS) is expected to fly on Space Station Alpha in 2004, and the Large Area Telescope (LAT) mission, that is part of the Gamma-Ray Large Area Space Telescope (GLAST), is planned for 2006. Both of these experiments are expected to lead to a better understanding of dark matter, high energy gamma ray sources, and the origin of the universe.

The **Nuclear Physics** (NP) program is the major sponsor of fundamental nuclear physics research in the Nation, providing about 90% of Federal support. NP's mission is to advance our knowledge of the properties and interactions of atomic nuclei and nuclear matter in terms of the fundamental forces and particles of nature; and, develop the scientific knowledge, technologies and trained manpower that is needed to underpin DOE's missions for nuclear-related national security, energy, and environmental quality.

In FY 2003, highest priority is given to enhancing the operations of the program's user facilities, especially major new facilities that have started operations: the Relativistic Heavy Ion Collider (RHIC) and Continuous Electron Beam Accelerator Facility (CEBAF). Funding for user facility operations will increase beam hours for research by about 21% over FY 2002. High priority is also given to university researchers who use these facilities and to nuclear theory activities in support of their programs.

The new RHIC facility at Brookhaven National Laboratory (BNL) has a unique opportunity to attempt to create and characterize the quark-gluon plasma, a phase of matter thought to have existed in the very early stage of the universe. Experimental data taken between FY 2000-2002 have already revealed unexpected behaviors and show aspects of possible plasma formation. RHIC achieved its planned full collision rate in FY 2002 and in FY 2003 the running schedule will be doubled, providing the opportunity to explore this exciting new physics in depth.

At the Thomas Jefferson National Accelerator Laboratory's CEBAF facility intense, polarized electron beams are being used to gain knowledge and insights on how quarks and gluons bind together to make protons and neutrons. In FY 2003, funding will support an aggressive experimental program with the newly completed G0 detector, to map out the strange quark contribution to the structure of the nucleon.

The unique research program studying the structure of the nucleon at the MIT/Bates facility with the BLAST detector, now being commissioned, will be initiated in FY 2003. Nuclear structure and astrophysics studies will be pursued at the three low-energy user facilities (ATLAS/ANL, 88-Inch Cyclotron/LBNL and HRIBF/ORNL) with increased running schedules compared to FY 2002.

A highlight of FY 2001 for the NP program was the reported measurements from the Sudbury Neutrino Observatory (SNO), providing an answer to a 30-year-old mystery – the puzzle of why there are less solar neutrinos detected than are expected. NP researchers found that the answer lies not with the Sun, but with the neutrinos that change their type (oscillate) as they travel from the core of the Sun to the Earth. In FY 2002-2005, SNO will make unique and more sensitive measurements of the flux and spectra of solar neutrinos. Neutrino oscillations are evidence that neutrinos have mass, an observation that forces a re-evaluation of the existing Standard Model of particle physics.

The **Biological and Environmental Research** (BER) program, in coordination with other Federal agencies and with guidance from the BER Advisory Committee, supports basic, peer-reviewed research at national laboratories and universities across a remarkable breadth of scientific fields ranging from global change to environmental remediation to genomics, proteomics, and medicine. The 21^{st} century has been called the “biological century” because advances in biology are expected to have an enormous impact on health, environment and our ability to predict climate change over decades and centuries. In FY 2003, the BER program will contribute to these advances through basic research in support of DOE missions.

Life sciences activities offer revolutionary advances for clean energy, mitigation of greenhouse gases, environmental cleanup, and detection and defeat of bioterrorism. Structural biology activities support facilities for scientists at synchrotron and neutron sources. A new station for small angle neutron scattering has been completed at Oak Ridge National Laboratory (ORNL), providing U.S. scientists with a much needed world-class facility**.** Genomes to Life activities develop novel research and computational tools that, together with capabilities in genomics, structural biology, and imaging will lead to an understanding of and predictive capabilities for complex biological systems. Human Genome research continues to develop advanced sequencing technologies needed by research and clinical scientists and provides high throughput DNA sequencing resources to address sequencing needs across the federal government, including biothreat reduction. Low Dose Radiation research will underpin a new scientific basis for determining the health risks from low dose ionizing radiation. The Laboratory for Comparative and Functional Genomics at ORNL will begin operations in FY 2003.

Climate Change Research underpins the Administration’s Climate Change Research Initiative (CCRI). Climate modeling research will improve regional and global scale simulations and predictions of climate. FY 2003 will see the development of an improved climate model with twice the spatial resolution of the previous version. Atmospheric Radiation Measurement research seeks to understand the role of clouds and solar radiation for use in climate models and to understand the water cycle to better predict precipitation patterns. Carbon and ecosystem research will underpin the CCRI objective to quantify the North American carbon cycle and to understand the effects of elevated carbon dioxide on terrestrial ecosystems.

The **Basic Energy Sciences** (BES) program is a principal sponsor of fundamental research for the Nation in the areas of materials sciences and engineering, chemistry, geosciences, and bioscience as it relates to energy. This research underpins DOE missions in energy, environment, and national security; advances energy related basic science on a broad front; and provides unique user facilities for the U.S. scientific community.

In FY 2003, BES will expand research in selected areas of nanoscale science, engineering, and technology (NSET) research and will continue design and begin construction for Nanoscale Science Research Centers (NSRCs). Fundamental research to understand the properties of materials at the nanoscale will be increased in three areas: synthesis and processing of materials at the nanoscale, condensed matter physics, and catalysis. The response of the scientific community to the NSET initiative has been strong.

Funds are requested in FY 2003 to start construction of the NSRC located at ORNL; and for continued engineering and design of a NSRC located at Lawrence Berkeley National Laboratory, and a NSRC with facilities at or collocated at Sandia National Laboratories (Albuquerque) and Los Alamos National Laboratory. NSRCs are user facilities for the synthesis, processing, fabrication, and analysis of materials at the nanoscale, and they will serve the Nation’s researchers broadly. These NSRCs were chosen from among those proposed through a peer review process.

A high priority in FY 2003 is continued construction of the Spallation Neutron Source (SNS) to provide the next-generation, short-pulse spallation neutron source for neutron scattering. The project, which is to be completed in June 2006, is on schedule and within budget with over one-third of the work completed as of the end of October 2001. At the end of FY 2003, construction of the SNS will be 61% complete.

The mission of the **Advanced Scientific Computing Research** (ASCR) program is to foster and support fundamental research in advanced scientific computing (applied mathematics, computer science, and networking) and to provide the high performance computational and networking tools that enable DOE to succeed in its science, energy, environmental quality, and national security missions. These tools are crucial if DOE researchers in the scientific disciplines are to maintain their world leadership.

In FY 2003, the ASCR program will continue to build on its leadership in high performance computing and networks by supporting the "Scientific Discovery through Advanced Computing" (SciDAC) program, and initiating new partnerships with the scientific disciplines in the Office of Science. SciDAC is a collaborative program across the Office of Science to produce the scientific computing, networking and collaboration tools that DOE researchers will require to address the scientific challenges of the next decade. This program was described in the March 2000 report to Congress entitled, "Scientific Discovery through Advanced Computing."

The SciDAC research portfolio will achieve several milestones in FY 2003. The Integrated Software Infrastructure Centers (ISICs) will complete design work and will deliver initial implementation of the software infrastructure on which the applications will rely for optimal performance and scalability on terascale platforms. The Applied Mathematics ISICs will deploy a suite of robust and scalable software solvers. The Computer Science ISICs will deploy software for high-throughput access to terascale datasets, and will deploy a collection of software tools for managing and monitoring large collections of distributed computing resources.

The **Fusion Energy Sciences** (FES) program leads the national research effort to advance plasma science, fusion science, and fusion technology—the knowledge base needed for an economically and environmentally attractive fusion energy source. The science and technology of fusion have progressed to the point that the next major research step is the exploration of the physics of a self-sustained plasma reaction in a burning plasma physics experiment. SC will fund research that supports such an experiment. In addition, SC will fund the exploration of innovative approaches to confining, heating, and fueling plasmas.

FES has two major thrusts in FY 2003. One is to begin the engineering design and fabrication of the National Compact Stellarator Experiment to be located at PPPL. It will provide scientists with a unique facility for studying the physics of this configuration related to, but with advantages relative to, the tokamak. The other is to enhance the operation of the three major fusion experiments by extending the operating weeks on each of them to 21 weeks in FY 2003.

Research funded by the FES program in FY 2001 produced results over a wide range of activities. Examples include: dramatic improvements in the feedback modification of plasma instabilities on the DIII-D experiment that doubled previous limits on plasma pressure; and the development, by researchers at the Alcator C-Mod, of a technique known as "off-axis ion cyclotron radio frequency heating" that can reduce energy transport. Greatly reduced energy transport has also been achieved in the Reversed Field Pinch (RFP), an innovative confinement concept experiment at the University of Wisconsin. Plasma turbulence simulation was improved through the development of new codes.

Science Program Direction (SCPD) enables a skilled, highly motivated Federal workforce to manage SC's basic and applied research portfolio, programs, projects, and facilities in support of new and improved energy, environmental, and health technologies, and educational opportunities. SCPD consists of three subprograms: Program Direction, Science Education, and Field Operations. The Program Direction subprogram supports Federal staff responsible for directing, administering, and supporting the broad spectrum of scientific disciplines. The Science Education subprogram supports four educational human resource development programs that train students to enter careers in science, mathematics, engineering, and technology. The Field Operations subprogram is the funding source for the Federal workforce in the Field responsible for management and administrative functions performed within the Chicago and Oak Ridge Operations Offices, and site offices supporting SC laboratories and facilities.

In FY 2002, SC initiated a reengineering effort throughout its headquarters and field organizations focused on increasing managerial flexibility, authority and accountability to reduce or avoid costs. This bottoms-up approach, across the SC complex, will form the basis for identifying SC's current or projected skills mix problems and how to address them. The SC reengineering effort will allow decision-making based on sound management principles to reduce administrative costs in field/laboratory operations and increase the span of control by FY 2003. The size of the field workforce will be reduced consistent with implementing positive organizational changes as a result of the studies underway.

In addition, SC will manage its Federal human capital to effectively respond to the science needs of the future and to the pending "brain-drain" that will be created by the fact that over 50% of SC's senior scientists will be retirement eligible within the next three years. Emphasis will be placed on obtaining additional human resources to support evolving research programs in several complex areas including nanoscale science, X-ray and neutron scattering, "Scientific Discovery through Advanced Computing", Global Climate Change, and "Genomes to Life." Preserving the intellectual capital and institutional knowledge vested in SC's senior Federal scientists and program managers is a high priority and will be a challenging task over the next five years. This is a dilemma faced by many agencies, but it is particularly acute and problematic for SC given the specialized scientific and programmatic knowledge, and technical qualifications required from potential replacements.

In support of these efforts to gain efficiencies through management improvements, SC is dedicating $5,500,000 to continue supporting a DOE-wide information technology project, the Corporate R&D Portfolio Management Environment (PME). Staff supporting PME are working with all of the Department's major R&D programs and other information technology projects to develop an integrated, end-to-end "corporate" electronic R&D management infrastructure that will enable cradle-to-grave tracking of projects and inter- and intra-program R&D portfolio management. This capability will foster R&D collaboration and support departmental responses to inquiries made by Congress, the Office of Management and Budget, and the Office of Science and Technology Policy using near-real-time data, in effect reducing overhead. PME is currently developing the first of three modules that will include application tool-sets that may be used for processing of proposals electronically.

The **Safeguards and Security** (S&S) program ensures appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or destruction of DOE assets and hostile acts that may cause adverse impacts on fundamental science, national security or the health and safety of DOE and contractor employees, the public or the environment. SC's Integrated Safeguards and Security Management strategy encompasses a tailored approach to safeguards and security. As such, each site has a tailored protection program that is analyzed and defined in their individual Security Plan. This approach allows each site to design varying degrees of protection commensurate with the risks and consequences described in their site-specific threat scenarios.

The FY 2003 request meets minimum, essential security requirements. Protection of employees and visitors is of primary concern, as well as protection of special nuclear material and research facilities, equipment and data. As such, priority attention is given to protective forces, physical security systems, and cyber security.

The mission of the **Science Laboratories Infrastructure** (SLI) program is to enable the conduct of Departmental research missions at SC laboratories by funding line item construction projects to maintain the general purpose infrastructure (GPI) and the clean up and removal of excess facilities. The program also supports SC landlord responsibilities for the 36,000 acre Oak Ridge Reservation and provides Payments in Lieu of Taxes (PILT) to local communities around ANL-E, BNL, and ORNL.

In FY 2003, the SLI program has been broadened to include all SC laboratories, both single purpose and multiprogram. A new subprogram, Excess Facilities Disposition, has been added to address the disposal of excess facilities at SC laboratories. Funding for FY 2003 is $5,055,000 and will eliminate or clean up 176,000 square feet of excess space. The new Facilities and Infrastructure (F&I) program funded by Congress at $10,000,000 in FY 2002, is being used to eliminate or clean up about 400,000 square feet of excess space. This F&I program was merged with the former Multiprogram Energy Laboratories – Facilities Support (MEL-FS) program to form the expanded SLI program in the FY 2003 request.

Construction funding for FY 2003 will increase by $9,800,000 over FY 2002 - reflecting the need to modernize SC laboratories. Three new construction starts are planned for FY 2003 including two buildings that will replace 71,000 square feet of space that cannot be economically renovated to support modern research.

The **Technical Information Management** (TIM) program, managed by the Office of Scientific and Technical Information (OSTI), in the Office of Science, provides electronic access to worldwide energy scientific and technical information to DOE researchers, U.S. industry, academia, and U.S. citizens. This is accomplished through a set of Internet-based information products for technical reports, scientific journals, and preprints – the three main sources in which scientific and technical information is recorded. In addition, the TIM program produces an inventory of R&D projects in progress across the Department.

In FY 2003, the TIM program will continue to lead DOE e-government initiatives for disseminating information, which include building the world's most comprehensive collection of physical sciences information and providing improved electronic access to full-text gray literature (literature not commercially available), journal literature, and preprints through partnerships with academia and the commercial sector.

The TIM program accomplishments for FY 2001 include expanded and increased access to published and pre-printed scientific and technical information via cost-effective information retrieval systems, resulting in a 25% increase in users served; completion of the DOE goal to transition to electronic scientific and technical reporting; taking a leadership role in the development of *science.gov*, the Interagency FirstGov for Science web resource; and launching the Energy Citations Database, a new web-based information product containing over 2,000,000 bibliographic records for energy and energy-related scientific and technical information from DOE and its predecessor agencies.

Science Strategic Objectives for FY 2003

This budget will support the Department of Energy's Science Goal:

Deliver the scientific knowledge and discoveries for DOE's applied missions; advance the frontiers of the physical sciences and areas of biological, environmental and computational sciences; and provide world-class research facilities and essential scientific human capital to the Nation's overall science enterprise.

For FY 2003, the Office of Science has established eight Strategic Objectives, with related Program Strategic Performance Goals (PSPGs) and Targets that will contribute to the Department of Energy's mission objectives in national defense, energy security, environmental quality, and science stewardship. The Performance Standards that will be used to evaluate the PSPGs and their Targets are described in Figure 6.

Performance Standards:	**Blue:**	Significantly exceeds expectations
	Green:	Meets all established targets/milestones
	Yellow:	Meets all critical targets/milestones
	Red:	Below expectation

Figure 6

The SC Strategic Objectives (**SC1** through **SC8**) and PSPGs (**SC1-1** through **SC7-6**) are:

SC1: Determine whether the Standard Model accurately predicts the mechanism that breaks the symmetry between natural forces and generates mass for all fundamental particles by 2010 or whether an alternate theory is required, and on the same timescale determine whether the absence of antimatter in the universe can be explained by known physics phenomena.

SC1-1: Exploit U.S. leadership at the energy frontier by conducting an experimental research program that will establish the foundations for a new understanding of the physical universe. (HEP Research and Technology subprogram and HEP Facilities subprogram)

SC1-2: Explain the observed absence of antimatter in the universe through understanding of the phenomenon of CP Violation. (HEP Research and Technology subprogram and HEP Facilities subprogram)

SC2: By 2015, describe the properties of the nucleon and light nuclei in terms of the properties and interactions of the underlying quarks and gluons; by 2010, establish whether a quark-gluon plasma can be created in the laboratory and, if so, characterize its properties; by 2020, characterize the structure and reactions of nuclei at the limits of stability and develop the theoretical models to describe their properties, and characterize, using experiments in the laboratory, the nuclear processes within stars and supernovae that are needed to provide an understanding of nucleosynthesis.

SC2-1: Determine the structure of nucleons in terms of bound states of quarks and gluons. Measure the effects of this structure on the properties of atomic nuclei. (NP subprograms in Medium Energy Nuclear Physics and Nuclear Theory)

SC2-2: Determine the behavior and properties of hot, dense nuclear matter as a function of temperature and density. Discover and characterize the quark-gluon plasma. (NP subprograms in Heavy Ion Nuclear Physics and Nuclear Theory)

SC2-3: Determine the low energy properties of nuclei, particularly at their limits of stability. Use these properties to understand energy generation and the origin of the elements in stars, and the fundamental symmetries of the "Standard Model" of elementary particle physics. (NP subprograms in Low Energy Nuclear Physics and Nuclear Theory)

SC3: By 2010, develop the basis for biotechnology solutions for clean energy, carbon sequestration, environmental cleanup, and bioterrorism detection and defeat by characterizing the multiprotein complexes that carry out biology in cells and by determining how microbial communities work as a system; and determine the sensitivity of climate to different levels of greenhouse gases and aerosols in the atmosphere and the potential resulting consequences of climate change associated with these levels by resolving or reducing key uncertainties in model predictions of both climate changes that would result from each level and the associated consequences.

SC3-1: Determine, compare, and analyze DNA sequences of microbes and other organisms that will underpin development of biotechnology solutions for clean energy, carbon sequestration, environmental cleanup, and bioterrorism detection and defeat. (BER subprograms in Life Sciences, Environmental Remediation, and Medical Applications and Measurement Science)

SC3-2: Establish the scientific foundation for determining a safe level of greenhouse gases and aerosols in the atmosphere by resolving or reducing key uncertainties in predicting their effects on climate, and provide the foundation to predict, assess and mitigate potential adverse effects of energy production and use on the environment. (BER Climate Change Research subprogram)

SC4: Provide leading scientific research programs in materials sciences and engineering, chemical sciences, biosciences, and geosciences that underpin DOE missions and spur major advances in national security, environmental quality, and the production of safe, secure, efficient, and environmentally responsible systems of energy supply; as part of these programs, by 2010, establish a suite of Nanoscale Science Research Centers and a robust nanoscience research program, allowing the atom-by-atom design of revolutionary new materials for DOE mission applications; and restore U.S. preeminence in neutron scattering research and facilities.

SC4-1: Build leading research programs in the scientific disciplines encompassed by the BES mission areas and provide world-class, peer-reviewed research results cognizant of DOE needs as well as the needs of the broad scientific community. (BES Materials Sciences and Engineering subprogram and BES Chemical Sciences, Geosciences, and Energy Biosciences subprogram)

SC4-2: Enable U.S. leadership in nanoscale science, allowing the atom-by-atom design of materials and integrated systems of nanostructured components having new and improved properties for applications as diverse as high-efficiency solar cells and better catalysts for the production of fuels. (BES Materials Sciences and Engineering subprogram and BES Chemical Sciences, Geosciences, and Energy Biosciences subprogram and the Advanced Scientific Computing Mathematical, Information and Computational Sciences subprogram)

SC4-3: Develop advanced research instruments for x-ray diffraction, scattering, and imaging to provide diverse communities of researchers with the tools necessary for exploration and discovery in materials sciences and engineering, chemistry, earth and geosciences, and biology. (BES Materials Sciences and Engineering subprogram and BES Chemical Sciences, Geosciences, and Energy Biosciences subprogram)

SC5: Enable advances and discoveries in DOE science through world-class research in the distributed operation of high performance, scientific computing and network facilities; and to deliver, in 2006, a suite of specialized software tools for DOE scientific simulations that take full advantage of terascale computers and high speed networks.

SC5-1: Build leading research programs in focused disciplines of applied mathematics, computer science, and network and collaboratory research important to national and energy security to spur revolutionary advances in the use of high performance computers and networks. (ASCR Mathematical, Information and Computational Sciences subprogram)

SC5-2: Create the *Mathematical and Computing Systems Software* and the *High Performance Computing Facilities* that enable Scientific Simulation and Modeling Codes to take full advantage of the extraordinary capabilities of terascale computers, and the *Collaboratory Software Infrastructure* to enable geographically-separated scientists to effectively work together as a team as well as provide electronic access to both facilities and data. (ASCR Mathematical, Information and Computational Sciences subprogram)

SC6: Advance the fundamental understanding of plasma, the fourth state of matter**,** and enhance predictive capabilities, through the comparison of well-diagnosed experiments, theory and simulation; for MFE, resolve outstanding scientific issues and establish reduced-cost paths to more attractive fusion energy systems by investigating a broad range of innovative magnetic confinement configurations; advance understanding and innovation in high-performance plasmas, optimizing for projected power-plant requirements; develop enabling technologies to advance fusion science, pursue innovative technologies and materials to improve the vision for fusion energy; and apply systems analysis to optimize fusion development; for IFE, leveraging from the ICF program sponsored by the National Nuclear Security Agency's Office of Defense Programs, advance the fundamental understanding and predictability of high energy density plasmas for IFE.

SC6-1: Develop the basis for a reliable capability to predict the behavior of magnetically confined plasma in a broad range of plasma confinement configurations and use the advances in the Tokamak concept to enable the start of the burning plasma physics phase of the U.S. fusion sciences program. (FES Science subprogram)

SC6-2: Develop the cutting edge technologies that enable FES research facilities to achieve their scientific goals, as well as allow the U.S. to access facility capabilities not available domestically, and investigate innovations needed to create attractive visions of design and technologies for fusion energy systems. (FES Enabling R&D subprogram)

SC7: Provide major advanced scientific user facilities where scientific excellence is validated by external review; average operational downtime does not exceed 10% of schedule; construction and upgrades are within 10% of schedule and budget; and facility technology research and development programs meet their goals. (Crosscutting all major programs)

SC7-1A: Manage HEP facility operations to the highest standards of performance, using merit evaluation with independent peer review. Meet U.S. commitments to the accelerator and detector components of the Large Hadron Collider (LHC) facility now under construction. (HEP Facilities subprogram)

SC7-1B: Perform the research and development needed to support the operation and upgrade of existing HEP facilities and to provide the tools and technology to develop new forefront facilities. (HEP Research and Technology subprogram)

SC7-2: Manage all NP facility operations and construction to the highest standards of overall performance, using merit evaluation with independent peer review. (NP subprograms in: Medium Energy Nuclear Physics, Heavy Ion Nuclear Physics, and Low Energy Nuclear Physics)

SC7-3: Manage all BER facility operations and construction to the highest standards of overall performance, using merit evaluation with independent peer review. (BER subprograms in: Life Sciences, Climate Change Research, Environmental Remediation, Medical Applications and Measurement Science)

SC7-4A: Manage BES facility operations and construction to the highest standards of overall performance using merit evaluation with independent peer review. (BES Materials Sciences and Engineering subprogram and BES Chemical Sciences, Geosciences, and Energy Biosciences subprogram)

SC7-4B: Restore U.S. preeminence in neutron scattering research, instrumentation, and facilities to provide researchers with the tools necessary for the exploration and discovery of advanced materials. (BES Materials Sciences and Engineering subprogram and BES Chemical Sciences, Geosciences, and Energy Biosciences subprogram)

SC7-5: Provide advanced computational scientific user facilities where scientific excellence is validated by external review; average operational downtime does not exceed 10% of schedule; construction and upgrades are within 10% of schedule and budget; and facility technology research and development programs meet their goals. (ASCR Mathematical, Information and Computational Sciences subprogram)

SC7-6: Manage all FES facility operations and construction to the highest standards of overall performance, using merit evaluation and independent peer review. (FES Facility Operations subprogram)

SC8: Ensure efficient SC program management of research and construction projects through a re-engineering effort of SC processes by FY 2003 that will support world-class science through systematic improvements in SC's laboratory physical infrastructure, security, and ES&H. (Covers the following accounts: Energy Research Analysis, Science Laboratories Infrastructure, Science Program Direction, Science Education, Field Operations, Safeguards and Security, Technical Information) Note: This Strategic Objective is supported by Program Strategic Performance Goals described within the detailed budget justification for each account.

Dr. James Decker
Director (Acting)
Office of Science

Table 1

OFFICE OF SCIENCE
FY 2003 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

	FY 2001 Comparable Approp.	FY 2002 Comparable Approp.	FY 2003 Pres. Request
Science			
Basic Energy Sciences	973,768	999,605	1,019,600
Advanced Scientific and Computing Research	161,296	157,400	169,625
Biological and Environmental Research	514,064	570,300	504,215
Fusion Energy Sciences	241,957	247,480	257,310
High Energy Physics	695,927	713,170	724,990
Nuclear Physics	351,794	359,035	382,370
Energy Research Analyses	950	995	1,020
Science Laboratories Infrastructure	26,887	37,130	42,735
Science Program Direction	139,861	152,475	139,479
Small Business Innovation Research and Small Business Technology Transfer	93,069	-	-
Subtotal	3,199,573	3,237,590	3,241,344
Safeguards and Security			
Safeguards and Security	39,081	47,609	48,127
Reimbursable Work	(4,648)	(4,460)	(4,383)
Total, Safeguards and Security	34,433	43,149	43,744
Total	3,234,006	3,280,739	3,285,088
Energy Supply			
Technical Information Management	9,204	8,049	8,353
Total	9,204	8,049	8,353

Table 2

OFFICE OF SCIENCE
FY 2003 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

	FY 2001 Comparable Approp.	FY 2002 Comparable Approp.	FY 2003 Pres. Request
Global Climate Change Research	115,624	120,168	126,169
High Performance Computing and Communications	171,471	174,449	185,704
Genomes to Life	3,000	24,514	44,542
Nanoscience Engineering and Technology	81,974	85,264	133,040

Table 3

OFFICE OF SCIENCE
FY 2003 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

Major Site Funding	FY 2001 Comparable Approp.	FY 2002 Comparable Approp.	FY 2003 Pres. Request
AMES LABORATORY			
Advanced Scientific and Computing Research	2,151	1,991	1,625
Basic Energy Sciences	17,961	16,114	16,507
Biological and Environmental Research	1,066	690	512
Safeguards and Security	264	397	409
Total Laboratory	21,442	19,192	19,053
ARGONNE NATIONAL LABORATORY			
Advanced Scientific and Computing Research	14,077	11,246	8,573
Basic Energy Sciences	159,028	154,389	152,734
Biological and Environmental Research	27,521	23,067	22,595
Fusion Energy Sciences	2,404	1,661	1,522
High Energy Physics	9,887	8,762	10,293
Nuclear Physics	17,912	16,532	17,548
Safeguards and Security	5,139	7,679	7,809
Science Laboratories Infrastructure	6,611	3,643	4,205
Science Program Direction	430	430	615
Total Laboratory	243,009	227,409	225,894
BROOKHAVEN NATIONAL LABORATORY			
Advanced Scientific and Computing Research	2,130	1,199	542
Basic Energy Sciences	75,942	56,606	57,398
Biological and Environmental Research	23,549	18,862	15,993
High Energy Physics	38,437	30,432	23,319
Nuclear Physics	140,791	138,671	149,004
Safeguards and Security	9,428	10,916	10,970
Science Laboratories Infrastructure	6,444	7,413	8,513
Science Program Direction	420	430	615
Total Laboratory	297,141	264,529	266,354

	FY 2000 Comparable Approp.	FY 2001 Comparable Approp.	FY 2002 Pres. Request
FERMI NATIONAL ACCELERATOR LABORATORY			
Advanced Scientific and Computing Research	120	226	60
Energy Research Analyses	22	-	-
High Energy Physics	306,567	304,791	313,340
Nuclear Physics	50	-	-
Safeguards and Security	2,430	2,763	2,837
Science Program Direction	50	20	100
Total Laboratory	309,239	307,800	316,337
IDAHO NATIONAL ENGINEERING LABORATORY			
Basic Energy Sciences	2,660	1,756	1,494
Biological and Environmental Research	1,440	1,056	400
Fusion Energy Sciences	2,210	2,326	2,392
Science Program Direction	40	10	-
Total Laboratory	6,350	5,148	4,286
LAWRENCE BERKELEY NATIONAL LABORATORY			
Advanced Scientific and Computing Research	65,807	51,325	53,223
Basic Energy Sciences	77,896	74,149	78,691
Biological and Environmental Research	61,970	50,133	44,821
Energy Research Analyses	50	-	50
Fusion Energy Sciences	5,510	5,861	5,799
High Energy Physics	40,694	37,817	32,530
Nuclear Physics	18,703	17,689	18,615
Safeguards and Security	3,492	4,706	4,753
Science Laboratories Infrastructure	2,113	7,400	5,607
Science Program Direction	445	480	750
Total Laboratory	276,680	249,560	244,839
LAWRENCE LIVERMORE NATIONAL LABORATORY			
Advanced Scientific and Computing Research	4,898	6,587	3,068
Basic Energy Sciences	5,643	4,793	4,676
Biological and Environmental Research	33,450	32,715	36,899
Fusion Energy Sciences	14,586	14,255	14,411
High Energy Physics	1,556	441	429
Nuclear Physics	755	614	507
Science Laboratories Infrastructure	-	350	250
Total Laboratory	60,888	59,755	60,240

	FY 2000 Comparable Approp.	FY 2001 Comparable Approp.	FY 2002 Pres. Request
LOS ALAMOS NATIONAL LABORATORY			
Advanced Scientific and Computing Research	5,727	2,855	5,020
Basic Energy Sciences	24,205	22,738	23,041
Biological and Environmental Research	22,447	19,848	18,681
Fusion Energy Sciences	7,258	7,378	7,308
High Energy Physics	1,075	869	825
Nuclear Physics	10,378	9,643	9,123
Science Program Direction	2,234	3,135	3,970
Total Laboratory	73,324	66,466	67,968
NATIONAL RENEWABLE ENERGY LABORATORY			
Basic Energy Sciences	5,876	5,247	4,562
Science Program Direction	-	-	150
Total Laboratory	5,876	5,247	4,712
OAK RIDGE NATIONAL LABORATORY			
Advanced Scientific and Computing Research	22,545	11,251	10,496
Basic Energy Sciences	374,386	391,333	343,176
Biological and Environmental Research	43,303	33,729	33,085
Fusion Energy Sciences	19,519	29,289	19,258
High Energy Physics	790	663	660
Nuclear Physics	15,879	15,307	16,870
Safeguards and Security	4,939	7,882	7,913
Science Laboratories Infrastructure	13,254	18,365	22,832
Total Laboratory	494,615	507,819	454,290
PACIFIC NORTHWEST NATIONAL LABORATORY			
Advanced Scientific and Computing Research	4,616	3,738	1,003
Basic Energy Sciences	13,024	11,346	11,648
Biological and Environmental Research	72,618	73,383	73,052
Energy Research Analyses	401	254	465
Fusion Energy Sciences	1,427	1,328	1,556
Science Laboratories Infrastructure	-	1,377	4,000
Science Program Direction	185	555	740
Total Laboratory	92,271	91,981	92,464

	FY 2000 Comparable Approp.	FY 2001 Comparable Approp.	FY 2002 Pres. Request
PRINCETON PLASMA PHYSICS LABORATORY			
Advanced Scientific and Computing Research	190	340	-
Basic Energy Sciences			
Fusion Energy Sciences	70,649	68,794	63,576
High Energy Physics	394	310	364
Safeguards and Security	1,735	1,828	1,855
Science Laboratories Infrastructure	-	875	545
Science Program Direction	110	125	100
Total Laboratory	73,078	72,272	66,440
SANDIA NATIONAL LABORATORY			
Advanced Scientific and Computing Research	4,656	4,767	3,889
Basic Energy Sciences	24,673	23,349	25,987
Biological and Environmental Research	3,474	3,391	2,737
Energy Research Analyses	200	5	100
Fusion Energy Sciences	3,178	2,992	3,213
High Energy Physics	4	-	-
Nuclear Physics	4	-	-
Total Laboratory	36,189	34,504	35,926
STANFORD LINEAR ACCELERATOR CENTER			
Advanced Scientific and Computing Research	315	502	234
Basic Energy Sciences	34,691	31,643	41,716
Biological and Environmental Research	3,656	4,170	5,550
High Energy Physics	159,503	164,545	163,887
Safeguards and Security	1,814	2,150	2,207
Science Laboratories Infrastructure	-	400	-
Science Program Direction	125	150	150
Total Laboratory	200,104	203,560	213,744
THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY			
Advanced Scientific and Computing Research	50	-	-
Biological and Environmental Research	155	400	500
High Energy Physics	5	-	-
Nuclear Physics	74,135	73,830	79,138
Safeguards and Security	552	947	972
Science Laboratories Infrastructure	-	-	1,500
Science Program Direction	45	50	100
Total Laboratory	74,942	75,227	82,210

Science

Proposed Appropriation Language

For Department of Energy expenses 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 **[**25**]** *28* passenger motor vehicles for replacement only, **[**$3,233,100,000**]** *$3,285,088,000*, to remain available until expended. *(Energy and Water Development Appropriations Act, 2002; additional authorizing legislation required.)*

High Energy Physics

Program Mission

The mission of the High Energy Physics (HEP) program is to understand the universe at a fundamental level by investigating the elementary particles that are the basic constituents of matter and the forces between them, thereby underpinning and advancing DOE missions and objectives through the development of key cutting-edge technologies and trained manpower that provide unique support to these missions. This program will provide world-class, peer-reviewed research results in HEP and related fields, including particle astrophysics and cosmology, executing a long-range strategy for high energy physics research and technology.

Strategic Objectives

SC1: Answer two key questions about the fundamental nature of matter and energy. Determine whether the Standard Model accurately predicts the mechanism that breaks the symmetry between natural forces and generates mass for all fundamental particles by 2010 or whether an alternate theory is required, and on the same timescale determine whether the absence of antimatter in the universe can be explained by known physics phenomena.

SC7: Provide major advanced scientific user facilities where scientific excellence is validated by external review; average operational downtime does not exceed 10% of schedule; construction and upgrades are within 10% of schedule and budget; and facility technology research and development programs meet their goals.

Progress toward accomplishing these Strategic Objectives will be measured by Program Strategic Performance Goals, Indicators and Annual Targets, as follows:

Program Strategic Performance Goals

SC1-1: Exploit U.S. leadership at the energy frontier by conducting an experimental research program that will establish the foundations for a new understanding of the physical universe. (Research and Technology subprogram and HEP Facilities subprogram).

Performance Indicator

Amount of data delivered and analyzed; Number of significant scientific discoveries.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Completed first phase of upgrades to enable the Tevatron at Fermilab to run with much higher luminosity. Began commissioning of phase-one accelerator upgrades. [Met Goal]	Deliver integrated luminosity as planned (80 pb-1) to CDF and D-Zero at the Tevatron. Begin implementation of second phase of accelerator upgrades: install four performance improvements to existing systems and begin design and construction of two new systems. (SC1-1)	Deliver integrated luminosity as planned (250 pb-1) to CDF and D-Zero at the Tevatron. Complete and install two new accelerator systems. Design new device to improve yield in antiproton target. (SC1-1)
Completed and commissioned upgrades of the CDF and D-Zero detectors at the Tevatron facility at Fermilab. [Met Goal]	Collect data and begin analysis. (SC1-1)	Take data with high efficiency; record over 60% of available data and continue analysis. (SC1-1)

SC1-2: Explain the observed absence of antimatter in the universe through understanding of the phenomenon of Charge Parity (CP) Violation (Research and Technology subprogram and HEP Facilities subprogram).

Performance Indicator

Amount of data delivered; Precision of final results; Number of significant scientific discoveries.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Delivered sufficient luminosity (25 fb-1) to double total BaBar data set. Added one new RF station. [Met Goal]	Increase the total data recorded by BaBar at the SLAC B-factory by delivering 35 fb-1 of total luminosity. (SC1-2)	Increase the total data delivered to BaBar at the SLAC B-factory by delivering 50 fb-1 of total luminosity. (SC1-2)
	Add one new RF station. (SC1-2)	Add one new RF station. Begin interaction region upgrade. (SC1-2)
BaBar collaboration published first unambiguous observation of CP violation in B meson decays. Errors on the measurement are +/- 0.15. [Met Goal]	Measure CP violation in B mesons with an uncertainty of +/- 0.12. (SC1-2)	Measure CP violation in B mesons with an uncertainty of +/- 0.10. (SC1-2)

SC7-1A: Manage HEP facility operations to the highest standards of performance, using merit evaluation with independent peer review. Meet U.S. commitments to the accelerator and detector components of the Large Hadron Collider (LHC) facility now under construction (HEP Facilities subprogram)

Performance Indicator

Percent on time/on budget, Percent unscheduled downtime.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
The completion figures for the U.S. portion of the LHC project were: CMS 61% ATLAS 61% Accelerator 68%	The completion targets for the U.S. portion of the LHC project are: CMS 77% ATLAS 72% Accelerator 85% (SC7-1A)	The completion targets for the U.S. portion of the LHC project are: CMS 85% ATLAS 82% Accelerator 92% (SC7-1A)
HEP scientific facilities were scheduled and operated such that unscheduled downtime on average is about 20% of scheduled operating time.	Maintain and operate HEP forefront scientific facilities such that unscheduled downtime is less than 20% of the total scheduled operating time. (SC7-1A)	Maintain and operate HEP forefront scientific facilities such that unscheduled downtime is less than 20% of the total scheduled operating time. (SC7-1A)

SC7-1B: Perform the research and development needed to support the operation and upgrade of existing HEP facilities and to provide the tools and technology to develop new forefront facilities. (Research and Technology subprogram).

Performance Indicator

Demonstration of R&D milestones and prototype components.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Demonstrated that 50 MV/m accelerating gradients in 11.4 GHz Next Linear Collider (NLC) accelerating structures are sustainable without significant structure damage.	Demonstrate operation of 11.4 GHz accelerating structure for an NLC at 75 MV/m without significant structural damage. (SC7-1B)	Demonstrate operation of advanced design accelerating structure for the NLC at 70 MV/m. (SC7-1B)
Successfully completed, at BNL, initial tests of carbon and mercury jet targets for the next generation of proton-driven accelerators.	Complete construction of Linac Test Area at BNL for detailed targeting & capture studies. (SC7-1B)	

Unique Opportunities for World Leadership

In FY 2003, the U.S. High Energy Physics program is focused on unique opportunities for great discoveries in physics. The Large Electron-Positron Collider (LEP) at CERN left a tantalizing hint of a *Higgs boson* when it ceased operations in late 2000. The data suggest a Higgs mass of about 115 GeV, well within reach of the Tevatron. The Higgs boson is associated with a field that is believed to give mass to the quarks and leptons, which are the fundamental constituents of matter. Its discovery would be a major advance in physics. The Large Hadron Collider (LHC) now being constructed in the LEP tunnel at CERN has been designed to find the Higgs, but cannot begin its physics program before 2006. Thus the Tevatron at Fermilab, with substantial upgrades completed and further improvements in progress, will have a chance to discover the Higgs before the LHC can get fully underway. With protons and antiprotons colliding head-on at an energy of nearly one trillion electron volts (1 TeV), the Tevatron is now at the world's energy frontier and will hold the lead until 2006. In order to find the Higgs by then, the Tevatron will need to run extensively, increase its luminosity (data rate) substantially, and replace some of its particle detectors components. A program of luminosity and detector improvements is now underway, interleaved with intensive data runs. If it is successful, the data in hand by the time LHC produces its first results should be enough to find the Higgs if its mass is less than 165 GeV. Tevatron data will also give more information about the surprisingly heavy *top quark* discovered there in 1995, and could reveal an entire new class of particles (*supersymmetric* particles) that have been predicted by new theories that seek to complete the unification of fundamental interactions.

At Stanford Linear Accelerator Center (SLAC), the highly successful B-factory and its BaBar detector will have the opportunity to shed light on the mysterious preponderance of matter over antimatter in the universe. Electrons colliding at several billion electron volts (GeV) will allow the study of a phenomenon known as *Charge-Parity (CP) violation* in B-mesons. B mesons contain a heavy b-quark or its anti-particle, and have roughly five times the proton mass. CP violation was originally discovered in 1964 in an experiment at Brookhaven National Laboratory involving the much lighter K mesons, and its accommodation within the current theory has only recently been established through extremely difficult and exquisitely precise measurements at Fermilab and CERN. The big question for SLAC is whether CP violation in the B-mesons will follow theoretical predictions or will instead indicate some additional, hitherto unknown source of the phenomenon. Such a discovery would have profound implications for our understanding of the matter-dominated universe in which we live. The B-factory will need a progressive series of upgrades in order to be competitive with a similar facility now operating in Japan that has three times more design luminosity. To fully exploit the discovery potential of the Tevatron at Fermilab and the B-factory at the SLAC along with their corresponding detectors as discussed above, these facilities must be strongly utilized and significantly upgraded. Therefore, the FY 2002 budget focused on the utilization and upgrades of these facilities together with support for the research groups (primarily university based) performing the research. Thus, the focus is on maximizing the discovery potential with lower priority being given to other parts of the program. The distribution of resources as specified in this budget continues this focused program.

Although the emphasis will be on the discovery potential at Fermilab and SLAC, there are other unique opportunities in the program.

The first results were announced in early 2001 from a precise measurement of the anomalous magnetic moment of the *muon*, one of the twelve fundamental constituents of matter. The measurement, from a dedicated experiment (called *g-2*) at Brookhaven's Alternating Gradient Synchrotron (AGS) accelerator, differs significantly from theoretical predictions. If this early result holds up after further analysis, it will be a signal of new physics beyond current theories. For example, it could mean that the supersymmetric particles mentioned above will indeed be discovered at the Tevatron. Final results are expected by 2003 after data analysis is completed. A long baseline neutrino detection experiment called MINOS (the Main Injector Neutrino Oscillation Search) is currently being fabricated at Fermilab, and the NuMI (Neutrinos at the Main Injector) beamline construction project will provide a dedicated beam of neutrinos for MINOS. Fermilab is also in the final stages of preparation for a smaller neutrino oscillation experiment, MiniBoone, which will take its first data in 2002. With NuMI/MINOS and MiniBoone, Fermilab will have the opportunity to confirm or refute early indications of neutrino mass and to make precise mass measurements. Positive results would require that the current theory of elementary particles and interactions be modified and that a non-zero neutrino mass be incorporated into a larger, more encompassing theory.

Major Advances

The DOE HEP program has been extremely successful. Since the DOE and its predecessors began supporting more than 90% of the research in this field around 1950, our understanding of the fundamental nature of matter has deepened profoundly, generating a stream of Nobel Prizes. Cutting edge experimental research at DOE accelerator laboratories in the 1960s and 1970s revealed a deeper level in the structure of matter, and theoretical physicists developed a new theory to explain it. Neutrons and protons, the building blocks of atomic nuclei, were shown to be tightly bound systems of more basic constituents called *quarks*. The last one, and the heaviest, was the top quark, found at Fermilab in 1995. DOE-supported university groups played major roles in all of these discoveries.

The strong force that binds quarks into nucleons is carried by particles called *gluons*, discovered at the DESY laboratory in Germany in 1978. The carriers of a second nuclear force, the weak interaction responsible for radioactivity, are called *W* and *Z bosons*, and they were discovered at the CERN Laboratory in Switzerland in 1983. The *photon*, which carries the electromagnetic force so familiar in our everyday lives, has been known since the turn of the twentieth century.

The discoveries of quarks and gluons revealed a deeper level of the structure of matter, a scientific advance that may be compared to the discovery of the atomic nucleus in the early twentieth century. This new knowledge is part of a theory known as the Standard Model, which identifies the basic constituents of matter and the fundamental forces that affect them. The theory also provides a mathematical structure to calculate properties of the particles and the ways they interact. The Standard

Model lists twelve fundamental constituents of matter (*fermions*): six quarks and six leptons. They occur in three families, each containing two quarks and two leptons. All three families are organized in the same patterns, but the members have different masses. There is strong evidence that no more families of quarks and leptons exist.

The theory includes three of the four known basic forces: the *strong, electromagnetic,* and *weak* forces, and twelve force carriers (called *bosons)*: eight gluons, two W's, the Z, and the photon. The fourth basic force, gravity, is not included. The quarks are subject to all four basic forces. The leptons (familiar examples are the electron and the neutrino) are subject to all of the basic forces except the strong force. Only two of the quarks—called *up* and *down*—are needed to make protons and neutrons. Thus these two quarks and just one of the leptons—the familiar electron—are sufficient to form all the stable matter that we observe on Earth. The Higgs field mentioned above is also an essential component of the Standard Model. A major role in establishing the Standard Model is one of the proudest accomplishments of the HEP program supported by the DOE and its predecessor agencies.

Major Questions

The Standard Model has been subjected to an array of rigorous tests for many years, and has survived all of them. It explains an amazing array of experimental data. Yet many important questions remain, many of which can be directly addressed through experiments:

What gives elementary particles their great variety of masses; is it the Higgs boson predicted by the Standard Model? Why are there exactly three families of quarks and leptons? Are these fermions truly the fundamental constituents of matter, or are they made of still smaller particles? Do the leptons called *neutrinos* really have no mass at all? Can gravity be incorporated into the Standard Model to make a complete theory of all particles and forces? Are there hidden, extra dimensions of space beyond the three we know? For every type of fermion, we have also created examples of its antiparticle (a kind of mirror image) but little of this *antimatter* is observed in the universe—why not? What is the *dark matter* that provides most of the mass in the universe, but emits no electromagnetic radiation? And what is the source of the recently observed acceleration in the expansion of the universe? Is there an undiscovered force or energy—the so-called *dark energy*?

Methods and Resources

Theoretical research in high energy physics develops theories of elementary particles and forces. A theory expresses what is known in mathematical form and provides a way to calculate particle properties and predict processes. Thus it predicts new phenomena that can be tested experimentally. Experimental work explores for new phenomena not predicted by theory, and tests specific theoretical predictions. It relies principally on particle accelerators and particle storage rings, where beams of particles collide with targets or with other beams. Accelerator experiments typically require large and complex apparatus (*detectors*) built and used by large collaborations of physicists and engineers from universities and laboratories. The scientists who design and oversee these large detectors are primarily faculty and staff at many of the nation's best universities (DOE-HEP supports research groups at over 100 U.S. universities). In addition, there are university scientists supported by the NSF, participating scientists at DOE labs (principally Fermilab, SLAC, Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), and Argonne National Laboratory (ANL)), and a substantial number of scientists from foreign institutions. Typically, these scientists work together in large international collaborations, involving hundreds of scientists from many institutions, to carry out a scientific program of experimentation that may take a decade or more to complete.

The main accelerator facilities in the United States are at two DOE laboratories: the Tevatron proton-antiproton collider at Fermilab in Illinois and the B-factory electron-positron collider at SLAC in California. Prior to its termination in FY 2003, HEP research was also conducted at the Alternating Gradient Synchroton at BNL. DOE scientists also use the Cornell Electron Storage Ring (CESR) electron-positron collider at Cornell (operated by NSF), and facilities in other countries. American scientists have long used facilities at the European Organization for Nuclear Research (CERN), near Geneva, Switzerland, and those facilities will be even more important to the DOE program in the future. CERN has just shut down its LEP electron-positron collider and is building the LHC, which will begin operations in 2006. Under an international agreement established in 1997, DOE in collaboration with the National Science Foundation (NSF), is providing substantial resources to help CERN build the collider itself and two major detectors (ATLAS and CMS). American scientists will participate strongly in research at the LHC.

Non-accelerator Experiments

It is important to note that while accelerators and accelerator- based experiments play a predominant role in the fields of high energy and nuclear physics, there are significant experiments that do not require the use of accelerators. Some of the non-accelerator experiments locate experimental apparatus on the earth's surface, others deep underground, and others in space. Non-accelerator experimentation is a growing part of the field of high energy physics and offers many exciting opportunities for the future.

Examples include the study of neutrinos coming from the sun, the search for dark matter, and the search for extremely rare processes such as proton decay or neutrino-less double beta decay, all of which require specialized detectors deep underground. Other non-accelerator experiments are located at ground level, such as the Pierre Auger project, in which a system of detectors will cover thousands of square kilometers and study the highest energy cosmic rays; and the Supernova Cosmology Project, which discovered the accelerating universe, suggesting the existence of dark energy.

Still others take place in space. For example, the Alpha Magnetic Spectrometer (AMS) detector will be located on the International Space Station to search for anti-matter in space, and the Gamma Large Area Space Telescope (GLAST) will be placed in earth orbit to study high energy gamma rays from "gamma ray bursters" and other astrophysical sources. This class of astrophysical phenomena is particularly interesting because it indicates that out in space there are concentrations of matter and acceleration mechanisms, and hence forces, far greater than any encountered here on earth.

Technical Requirements

High energy physics works with particle energies higher than exist anywhere but in certain stellar or cosmological environments and studies distance scales that are extraordinarily small. It often must make precision measurements of phenomena buried in a background of noise or search for very rare processes that may signal new physics. Such research demands particle beams of great intensities and detectors with both the sensitivity to see the rare events and the selectivity to pull these out of a cacophony of background noise. It requires accelerators and storage rings that operate at trillions of electron volts of energy and particle currents that can routinely burn holes in steel, and demands particle detectors that can identify one particle out of several thousand and catch particles that live less that a trillionth of a second. It is essential to accumulate, store, process, and transmit to hundreds of researchers worldwide the increasingly large data sets produced by modern experiments. As international collaborations in high energy physics grow from roughly 500 physicists presently working at each CERN, Fermilab, and SLAC detector to approximately 1800 in each of the collaborations preparing detectors for the LHC, the need for sophisticated data handling at widely separated data centers becomes even more crucial.

Operating in these extreme domains requires substantial time and expense to design, build, maintain, operate, and upgrade the impressively complex and technically advanced research apparatus. A new accelerator or colliding beam device now requires 10 to 20 years of intensive research and development work to bring a new technology to the point of cost effective construction, and a similar effort is required for detectors and computing systems. The R&D programs to sustain a forefront science program are unavoidably big, costly, and long-term. Since few of the core technologies for these devices are marketable, industry has no motivation to research, develop, or manufacture the key technical items, except as (usually expensive) special procurements. Consequently, in order to advance the science, it is essential for the universities and national laboratories engaged in high energy physics to develop the cutting edge technologies that are needed.

Benefits to Other Sciences and to Citizens

High energy physics is profoundly connected to nuclear physics and to astrophysics and cosmology. Advances in any one of these fields often have a strong impact on one another. A principal objective of nuclear physics research now is to incorporate the quark discovered by high energy physics into the understanding of nuclear structure. High energy physics, nuclear physics, and astrophysics detectors use many of the same techniques.

Technology that was developed in response to the demands of high energy physics has become exceedingly useful to other fields of science, and thus has helped science to advance on a broad front. Synchrotron light sources, an outgrowth of electron accelerators and storage rings, have become invaluable tools for materials science, structural biology, chemistry, environmental science and medical science. Accelerators are used for radiation therapy and to produce isotopes for medical imaging. In U.S. hospitals, one patient in three benefits from a diagnostic or therapeutic nuclear medicine procedure, techniques derived from research in high energy and nuclear physics. The World Wide Web was invented by high energy physicists to transport large bodies of data among international collaborators and has brought about a worldwide revolution in communications and commerce. International research collaborations in high energy physics have set an example for other endeavors that require cooperative efforts by thousands of workers who must share facilities, data, and results, communicating among continents and managing the activities of diverse groups.

An important product of the HEP program is the corps of graduates trained in this discipline. This is a group of very talented people, well versed in scientific methods and state-of-the-art technologies, and skilled at working in teams. Many of them go into careers in high-tech industries, contributing to our country's economic strength.

Accelerator Research and Development

The Department is continuing research and development directed toward accelerator facilities that will be needed for the future. Several approaches are being investigated. One is a linear electron-positron collider, often called the Next Linear Collider (NLC), following the successful example of the SLAC Linear Collider. Work is directed toward achieving a center-of-mass energy in the TeV range (500 to 1000 GeV, expandable to 1.5 TeV. A GeV is one billion electron volts of energy.). The current NLC R&D program, led by SLAC and Fermilab, seeks to develop new technologies that would provide high performance while limiting cost. The R&D develops new technologies, applies available technologies, and uses industrial firms to expand its R&D reach on certain technologies and to engage in necessary technology transfer. A facility like the NLC may well be international, and research and development on linear colliders is also underway in other countries, primarily Germany and Japan.

Research is also underway on a storage ring for muons rather than electrons. Radiation losses of energy from the beam would be less than for electrons and thus a circular machine could be used. The challenge for any accelerator based on muons is their short lifetime (two millionths of a second), which demands very rapid production and acceleration of the beams. Fortunately, relativistic time dilation means a muon lives longer the faster it is moving through the laboratory. The decays of muons in a storage ring could also provide an intense source of neutrinos, and this idea (known as the "neutrino factory") is being actively investigated. Physicists also are investigating the more technically challenging possibility of a storage ring that could serve as a muon collider.

In spite of the more complicated interactions of its "bags of quarks," for energies well beyond the LHC, the best discovery machine may still be a high energy hadron collider, with its broad range of physics interactions. Work is underway at several laboratories and universities toward designing magnets that could make possible an affordable very high energy hadron collider. Such a facility could have collision energy of greater than 100 TeV, much higher than that of the LHC.

Significant Accomplishments and Program Shifts

Research and Technology

SCIENCE ACCOMPLISHMENTS

DOE's High Energy Physics Program has a long and rich history of producing world-class research, much of which has been recognized by Nobel Prizes in Physics. Theoretical research supported by the program was responsible for the initial formulation of the Standard Model, and DOE-supported researchers at universities and laboratories provided much of its experimental basis including discovery of all of the quarks and most of the leptons. Specifically, DOE-supported research produced the following major accomplishments.

- 1950's: Theoretical prediction of Columbia University physicists that parity is not conserved in weak interactions (1957 Nobel Prize)
- 1950's: Discovery of the electron neutrino by Los Alamos National Laboratory scientists using the Savannah River Plant (1995 Nobel Prize)
- 1963: Discovery of the muon neutrino at Brookhaven National Laboratory (1988 Nobel Prize)
- 1964: Quark model of elementary particle physics proposed by a CalTech physicist (1969 Nobel Prize)
- 1964: Discovery of the omega-minus particle at Brookhaven National Laboratory, demonstrating the existence of the strange quark and supporting the quark model
- 1964: Discovery of charge-parity (CP) violation in K mesons at Brookhaven National Laboratory (1980 Nobel Prize)
- 1968: Experimental basis for up and down quarks at the Stanford Linear Accelerator Center (1990 Nobel Prize)
- 1974: Discovery of the charm quark at the Stanford Linear Accelerator Center and Brookhaven National Laboratory (1976 Nobel Prize)
- 1975: Discovery of the tau lepton at the Stanford Linear Accelerator Center (1995 Nobel Prize)

- 1977: Discovery of the bottom quark at Fermi National Accelerator Laboratory
- 1995: Discovery of the top quark at Fermi National Accelerator Laboratory
- 2000: Discovery of the tau neutrino at Fermi National Accelerator Laboratory
- 2001: Discovery of CP violation in B mesons at the Stanford Linear Accelerator Center

FY 2001 accomplishments are summarized below:

- The tau neutrino was discovered by the DONUT collaboration, a team of university and laboratory scientists working at Fermilab. This completed the last generation of leptons, and capped a major American achievement: the discovery of 11 of the 12 basic constituents of matter, the quarks and leptons of the Standard Model of elementary particles. (The first of the 12, the electron, had been discovered in England in 1897.) The discovery of the tau neutrino was considered by the American Institute of Physics to be one of the top three physics news stories of the year 2000, and has been published in peer reviewed scientific journals.
- University groups from the United States working on experiments at the LEP electron-positron collider at CERN completed their final data collection during FY 2000. Early analysis gave tantalizing indications that the Higgs boson may have been produced at LEP. Although not a definitive discovery, this finding was considered one of the top three physics news stories of the year 2000. The data analysis should be completed in 2002. Discovery and study of the Higgs boson, believed to be the source of mass for all elementary particles, is a major objective of the LHC, and will be vigorously pursued before the LHC by the Tevatron Collider at Fermilab.
- In 2001, physicists using the new BaBar detector at the new SLAC B-factory announced a definitive measurement of CP violation in the B-meson system. American physicists also participated in the BELLE experiment at the Japanese KEK laboratory, which reported similar measurements. The two results are consistent with each other, and with an earlier, less precise measurement from CDF at the Fermilab Tevatron. They are also consistent with the current Standard Model description of CP violation. Data collection continues with high priority to improve the precision of the result.
- The g-2 experiment at BNL, designed to study magnetic properties of the muon, has obtained the most precise measurement of the muon anomalous magnetic moment. Preliminary results announced in 2001 do not quite agree with the Standard Model, suggesting a first glimpse of new physics. The measurement precision should improve by a factor of two as analysis proceeds and more data are collected. If this result is confirmed, it would be the first clear indication of new physics beyond the Standard Model.
- Theoretical studies have led to a prediction that the “missing dimensions” in string theories may, under certain circumstances, be experimentally detectable, thus suggesting a way to test the validity of this class of theories.
- A SLAC 30 GeV electron beam was directed through a 1.5-meter segment of lithium plasma, creating a plasma wave that exhibited an accelerating gradient of greater than 0.5 GeV per meter. This is a record in a program that may have a potential of eventually approaching accelerating gradients of 10’s of GeV per meter.
- Further evidence was obtained by studying very distant Supernovae of Type Ia that the universe is accelerating outward under the influence of an unknown force (dubbed “dark energy”) that may comprise 70% of the critical density of the Universe. This result was obtained utilizing techniques adapted from HEP, and agrees with earlier results obtained by DOE researchers using completely different methods. The original discovery of the accelerating universe was Science magazine’s Top Science Story of 1998.

High Energy Physics Facilities

FACILITY ACCOMPLISHMENTS

- The Tevatron completed commissioning with the new Main Injector, and the two upgraded detectors (CDF and D-Zero) were brought into operation in FY 2001. FY 2003 will be the second full year of operation to exploit these new capabilities.
- The B-factory at SLAC was brought into full operation during the early part of FY 2000 and has achieved and surpassed design luminosity. During FY 2003, the B-factory will be operated for maximum data collection on the key scientific question of understanding matter-antimatter asymmetry in the universe.
- The new BaBar detector at the B-factory at SLAC became fully operational in FY 2000 and performed very well in FY 2002, collecting and analyzing data at a high rate.
- A formal program has been initiated to develop, design and implement a computing system to process, store and support the analysis of the huge amount of data anticipated when the LHC begins physics operation in FY 2006.

PROGRAM SHIFTS

- Research with the CDF and D-Zero detectors at the Tevatron and the BaBar detector at the B-factory will continue to receive priority emphasis to take advantage of the major science opportunities described above.
- For the same reason, a number of planned upgrades to both facilities intended to increase the luminosity and improve the machine and detectors are being given high priority. These include upgrades to the two accelerators to provide increased luminosity, detector component replacements to accommodate the higher intensities, and additional computational resources to support analysis of the anticipated larger volume of data. Lower priority parts of the program will be reduced.
- A long range planning study of the High Energy Physics program, entitled "Planning for the Future of U.S. High Energy Physics," was prepared in 1998 by a Subpanel of the High Energy Physics Advisory Panel (HEPAP). The Subpanel's recommendations were considered carefully in preparing this budget.
- An update of this report, entitled "HEPAP White Paper on Planning for U.S. High Energy Physics," has recently been prepared by HEPAP and was also used in planning this budget.
- A new HEPAP Subpanel has been assembled and charged to prepare an updated long range planning report. This report is expected early in 2002.
- DOE is establishing an exciting and expanding partnership with NASA in the area of Particle Astrophysics. The Alpha Magnetic Spectrometer (AMS) and Gamma Large Area Space Telescope (GLAST) experiments have been underway for some time. Preliminary consideration is being given to the interagency SuperNova Acceleration Probe (SNAP) experiment. These experiments, and others that may be proposed, will provide important new information about cosmic rays and the rate of expansion of the universe which will in turn lead to a better understanding of dark matter, dark energy, and the original big bang. The AMS and GLAST experiments, which are joint DOE-NASA projects, have received NASA mission approval.
- The Neutrinos at the Main Injector project has encountered serious problems in several areas. These include the construction of the beam tunnel at Fermilab and design changes in the beam line components and shielding needed to accommodate the high radiation levels resulting from the very

high intensity of the proton beam used to produce the neutrinos. The MINOS detector for NuMI, is proceeding well, and completion is expected within the projected cost and schedule. Because of these developments, the project costs have risen. The TPC is increased to $171,442,000 from the previously approved $139,390,000, and the TEC is increased to $109,242,000 from the previously approved $76,149,000. The completion is delayed by about two years to the end of FY 2005.

Scientific Facilities Utilization

The High Energy Physics request includes $480,453,000 to maintain support of the Department's scientific user facilities. This investment will provide significant research time for several thousand scientists based at 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). In FY 2003, the Alternating Gradient Synchrotron at Brookhaven National Laboratory is terminated for High Energy Physics research.

Workforce Development

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

About 1,000 post-doctoral associates and graduate students supported by the High Energy Physics program in FY 2001 were involved in a large variety of theoretical and experimental research, including advanced technology R&D. About one-fifth are involved in theoretical research. Those involved in experimental research utilize a number of scientific facilities supported by the DOE, NSF, and foreign countries. The majority of the experimental postdoctoral associates and graduate students have worked at one of the three High Energy Physics User Facilities: Fermi National Accelerator Laboratory, Stanford Linear Accelerator Center, and Brookhaven National Laboratory.

Funding Profile

(dollars in thousands)

	FY 2001 Comparable Appropriation	FY 2002 Original Appropriation	FY 2002 Adjustments	FY 2002 Comparable Current Appropriation	FY 2003 Request
High Energy Physics					
Research and Technology	240,653	247,870	-3,645 [a]	244,225	258,545
High Energy Physics Facilities	422,945	456,830	+715 [a]	457,545	446,352
Subtotal, High Energy Physics	663,598	704,700	-2,930	701,770	704,897
Construction	32,329	11,400	0	11,400	20,093
Subtotal, High Energy Physics	695,927	716,100	-2,930	713,170	724,990
General Reduction	0	-2,930	+2,930	0	0
Total, High Energy Physics	695,927 [b] [c]	713,170	0	713,170	724,990

Public Law Authorization:

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

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

[a] Funding in the amount of $2,455,000 transferred from Research and Technology to High Energy Physics Facilities to more appropriately account for LHC program support.

[b] Excludes $14,409,000 which has been transferred to the SBIR program and $865,000 which has been transferred to the STTR program.

[c] Excludes $800,000 which was transferred to the Science Safeguards and Security program in an FY 2001 reprogramming.

Funding by Site

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	1,075	869	825	-44	-5.1%
Sandia National Laboratory...................	4	0	0	0	--
Total, Albuquerque Operations Office	1,079	869	825	-44	-5.1%
Chicago Operations Office					
Argonne National Laboratory	9,887	8,762	10,293	+1,531	+17.5%
Brookhaven National Laboratory...........	38,437	30,432	23,319	-7,113	-23.4%
Fermi National Accelerator Laboratory..	306,567	304,791	313,340	+8,549	+2.8%
Princeton Plasma Physics Laboratory...	394	310	364	+54	+17.4%
Chicago Operations Office	88,336	80,590	74,527	-6,063	-7.5%
Total, Chicago Operations Office	443,621	424,885	421,843	-3,042	-0.7%
Nevada Operations Office...........................	30	0	0	0	--
Oakland Operations Office					
Lawrence Berkeley National Laboratory	40,694	37,817	32,530	-5,287	-14.0%
Lawrence Livermore National Laboratory	1,556	441	429	-12	-2.7%
Stanford Linear Accelerator Center	159,503	164,545	163,887	-658	-0.4%
Oakland Operations Office	39,020	37,245	44,000	+6,755	+18.1%
Total, Oakland Operations Office.................	240,773	240,048	240,846	+798	+0.3%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education	330	5	130	+125	+2,500.0%
Oak Ridge National Laboratory.............	790	663	660	-3	-0.5%
Thomas Jefferson National Accelerator Facility.	5	0	0	0	--
Oak Ridge Operations Office.................	15	0	0	0	--
Total, Oak Ridge Operations Office	1,140	668	790	+122	+18.3%
Washington Headquarters	9,284	46,700	60,686	+13,986	+29.9%
Total, High Energy Physics	695,927 [a] [b]	713,170	724,990	+11,820	+1.7%

[a] Excludes $14,409,000 which has been transferred to the SBIR program and $865,000 which has been transferred to the STTR program.

[b] Excludes $800,000 which has been transferred to the Science Safeguards and Security program in an FY 2001 reprogramming.

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. 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 advanced accelerator and computing techniques.

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) 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 its capability for precise experimental measurement. High Energy Physics has also made limited use of the Alternating Gradient Synchrotron (AGS), a 28 GeV proton accelerator, which is principally supported by the Nuclear Physics program. Use of the AGS for HEP experiments will be terminated at the end of FY 2002.

Fermi National Accelerator Laboratory

Fermi National Accelerator Laboratory (Fermilab) 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 an energy of one trillion electron volts (1 TeV). The Tevatron is the highest energy proton accelerator in the world, and will remain so until the LHC begins physics operation in 2006. With the recent shutdown of the LEP machine at CERN in Switzerland, the Tevatron became the only operating particle accelerator at the energy frontier. Fermilab also includes the Main Injector, a pre-accelerator to the Tevatron. The Main Injector is also used to produce antiprotons for the Tevatron and will be used independently of the Tevatron for a 120 GeV fixed target program. Fermilab and SLAC are the principal experimental facilities of the DOE High Energy Physics program.

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. 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 expertise in superconducting magnet R&D, world-forefront expertise in laser driven particle acceleration, expertise in design of forefront electronic devices, and design of modern, complex software codes for acquisition and analysis of data from HEP experiments.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a multiprogram laboratory located on an 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.

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. 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 development of computational techniques for accelerator design.

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. 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 (ORNL) 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. Through the Scientific Discovery through Advanced Computing (SciDAC) program, HEP will support an effort to model the physics processes that drive supernova explosions.

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 High Energy Physics program supports a small theoretical research effort using unique capabilities of PPPL staff in the area of advanced accelerator R&D.

Sandia National Laboratory

Sandia National Laboratory (SNL) is a multiprogram laboratory located on a 3,700-acre site in Albuquerque, New Mexico, with other sites in Livermore, California and Tonopah, Nevada. The High Energy Physics program supports a small effort at SNL in the area of logic modeling.

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 operates for High Energy Physics the recently completed B-factory and its detector, BaBar, and a program of fixed target experiments. The B-factory, a high energy electron-positron collider, was constructed to support a high quality search for and study of CP symmetry violation in the B meson system. All of these facilities make use of the two-mile long linear accelerator, or linac. SLAC and Fermilab are the principal experimental facilities of the DOE High Energy Physics program.

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 dedicated to the exploration of nuclear and nucleon structure. Through the SciDAC program, the High Energy Physics program supports an R&D effort aimed at computer modeling of the fundamental interactions between quarks and gluons, and a collaborative effort to develop software tools for data-intensive computing.

All Other Sites

The High Energy Physics program supports about 260 research groups at more than 100 colleges and universities located in 37 states, Washington, D.C., and Puerto Rico. The strength and effectiveness of the university-based program is critically important to the success of the program as a whole. This university-based component of the HEP program provides access to some of the best scientific talent in the nation, and train the next generation of scientists.

The High Energy Physics program also directly funds research at a small number of non-DOE laboratories and non-government laboratories and institutes (e.g., National Institute for Standards and Technology, Naval Research Laboratory, the Smithsonian Institute), and a few small companies. Through its participation in the SBIR and STTR programs, the DOE HEP program also supports advanced technology R&D at some 60 small businesses located throughout the U.S.

Research and Technology

Mission Supporting Goals and Objectives

During the next five years, the DOE High Energy Physics program (HEP) will maintain its position as a world leader in experimental and theoretical research toward the fundamental understanding of matter, space, and time. It will provide the world's highest energy collisions at Fermilab's Tevatron, offering the best opportunity to explain how elementary particles get their mass. The B-factory will operate as one of the world's two electron-positron colliders that could explain the lack of antimatter in the universe.

The United States will execute its long-range strategy for high energy physics research and technology, with important input and consensus from the 20-year "roadmap" submitted by the High Energy Physics Advisory Panel (HEPAP) to DOE in 2002.

- HEP will perform the research and development needed to support and improve the operation of existing facilities—both accelerators and detectors—and to support the design and construction of new facilities needed to maintain our leading role in high energy physics research.
- The HEP program, which is the U.S. leader in sponsoring accelerator technology R&D with long-term applications spanning both the physical and the life sciences, will also search for completely new principles that could substantially increase the efficiency and performance of future accelerators.
- Resources provided for the Scientific Discovery through Advanced Computing (SciDAC) initiative will be used to support work on lattice Quantum Chromodynamics (QCD) computation of fundamental particle physics parameters, work on simulations of complex accelerators, and work on the design and utilization of distributed computer systems.
- The Research and Technology subprogram provides support for the university and laboratory based research groups carrying out the planned physics research and technology development programs for FY 2003 described below and planning the programs to be carried out in future years.

Physics Research

The Physics Research category in the Research and Technology subprogram supports the university and laboratory based scientists performing experimental and theoretical HEP research.

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 investigation. The research groups are based at ANL, BNL, Fermilab, LANL, LBNL, LLNL, ORNL, and SLAC, and about 100 colleges and universities.

The major planned Physics Research efforts in FY 2003 are:

- THE RESEARCH PROGRAM AT THE B-FACTORY/BABAR FACILITY AT SLAC. This research program is being carried out by a collaboration including scientists from SLAC, LBNL, LLNL, ORNL, 31 U.S. universities, and institutions from 6 foreign countries.
- THE RESEARCH PROGRAM USING THE TEVATRON/CDF FACILITY AT FERMILAB. This research program is being carried out by a collaboration including scientists from Fermilab, ANL, LBNL, 25 U.S. universities, and institutions in 10 foreign countries.
- THE RESEARCH PROGRAM USING THE TEVATRON/D-ZERO FACILITY AT FERMILAB. This research program is being carried out by a collaboration including scientists from Fermilab, BNL, LBNL, 33 U.S. universities and institutions in 16 foreign countries.
- A program of theoretical research at both universities and laboratories to identify questions for future research, and to further the understanding of new experimental results.
- A group of experimental research activities using the Cornell Electron Storage Ring and various international accelerator facilities with special capabilities, and other experimental activities, which do not require an accelerator beam.
- A small program of generic detector R&D.

High Energy Physics Technology

The High Energy Physics Technology category in the Research and Technology subprogram provides support for the specialized advanced technology R&D required to sustain and upgrade the presently operating facilities, to support accelerator and detector facilities presently under construction, and to extend the technology base so as to make possible new accelerator and detector technologies which will be needed to continue advancing the frontiers of the field.

The major planned High Energy Physics Technology efforts in FY 2003 are:

- SUPPORT FOR R&D RELATED TO EXISTING FACILITIES AND FACILITIES UNDER CONSTRUCTION. This R&D ensures the cost-effective performance of the facility, the ready adaptation for new research requirements, and the machine and detector performance improvements needed to address new research frontiers. This R&D is carried out at Fermilab, and SLAC.
- SUPPORT FOR GENERAL TECHNOLOGY R&D. A component of the R&D at each of the HEP laboratories is focused on improvements in the general areas of technology important at that laboratory but not directly connected to the operating machine or a facility under construction. The principal activities are R&D on high field superconducting accelerator magnets, improved radiofrequency acceleration, new beam instrumentation, and new detection technologies.
- SUPPORT FOR R&D RELATED TO A POSSIBLE FUTURE MUON STORAGE RING (NEUTRINO SOURCE). The muon is over 200 times heavier than an electron, but otherwise very similar in properties. The mass of the muon effectively eliminates the radiation losses, which severely limit circular electron machines. Thus a muon colliding beam machine, if it can be made to work, is an attractive alternate approach to research needing high energy colliding beams of leptons. Moreover, the decay of the circulating muons can result in a well-collimated, very intense beam of

neutrinos, with additional interesting physics possibilities, such as searching for evidence of neutrino mass.

The technical requirements for this new kind of accelerator present major challenges to the development of extremely high power beam targets, high power radio frequency systems, and intense beam transport systems. This R&D program involves a collaboration of national laboratories and universities.

- SUPPORT FOR LINEAR COLLIDER R&D. It has been long recognized that lepton and proton colliders provide very complementary capabilities and there is general agreement in the research community that it is essential for the HEP program to pursue both techniques to the highest possible energies, for which a lepton-collider complement to the LHC is needed.

  This approach to LHC scale energies was first demonstrated with the operation of the Stanford Linear Collider (SLC) at SLAC. Following on the success of the SLC, an international R&D collaboration (with SLAC as a major participant) has identified and attacked the technical barriers to the construction of a TeV scale linear collider. The SLAC version of this concept is called the Next Linear Collider (NLC). The R&D program focused on solution of the technical challenges related to building TeV scale linear electron-positron colliders is being carried out on an international basis. The international collaboration includes the Japanese high energy physics center, KEK, through a SLAC-KEK inter-laboratory memorandum of understanding, and by less formal arrangements, with R&D groups at the German DESY Laboratory, CERN, and the Budker Institute in Russia. The U.S. is a world leader in this R&D program. The NLC program is being carried out by a national collaboration that includes SLAC as the principal laboratory, Fermilab as the major collaborator, and with significant contributions from Lawrence Berkeley National Laboratory and Lawrence Livermore National Laboratory.

  The specific goals of the present NLC R&D program include developing new technologies that enable a higher performance, lower cost machine; carrying out systems engineering, value engineering, and risk analysis studies to identify additional R&D issues that could effect cost and performance and to select from available technologies; and using industrial firms to carry out R&D on selected technologies, thus exploiting the special "design-for-manufacture" expertise available in industry and effecting technical transfer from the NLC R&D program to industry. In addition, cost analysis and scheduling tools are being developed that can be used to guide the R&D program by identifying cost driving technologies. In FY 2003, the R&D program led by Fermilab and SLAC will focus on reliably achieving accelerating gradients in radio frequency structures in the required range of 75 to 100 MeV/meter.

- SUPPORT FOR FUTURE ORIENTED R&D. Advances in HEP are strongly dependent upon the development of new, higher-performance research instruments. The principal technologies that have been used to produce high particle energies are radio frequency acceleration and high field magnets. Today, the needs of high energy physics are pushing these technologies to limits unimagined twenty years ago. To respond, HEP funds an Advanced Accelerator R&D program looking for new approaches to these underlying technical needs. A further goal is to support a program for graduate training in the science and technologies underlying charge particle beam sources – the accelerators and storage ring systems essential to forefront research in high energy particle physics. To this end, the DOE/HEP Advanced Accelerator R&D program supports an extensive university-based and laboratory based accelerator physics program. The range of topics explored in the Advanced Accelerator R&D activity is very broad, but the principal goals are improved accelerating systems, stronger and more precise beam focusing systems, and improved mathematical understanding and computer modeling of accelerators.

Conventional radio frequency accelerating systems probably cannot operate above gradients of 100 to 200 million volts per meter, so the use of lasers and plasmas as advanced accelerating devices is being studied. Today's magnetic fields (e.g., LHC magnets) routinely reach up to about 10 Tesla. This Advanced Accelerator R&D program has as a goal, magnets that can operate at 16 to 18 Tesla and are cost effective to build. This goal requires improved industrially available superconductors and new magnet geometries and structures and all of these are being explored. A major part of the research program is devoted to developing new theoretical, mathematical and computational approaches. These efforts focus heavily on the areas of classical non-linear dynamics, space charge dominated charged particle beams, and physical phenomenon associated with plasma waves moving close to the speed of light.

This Advanced Accelerator R&D research is carried out at ANL, BNL, LBNL, LANL, two non-DOE laboratories (Naval Research Laboratory and National Institute for Science and Technology), and thirty-four universities, the largest programs being at the University of Maryland and University of California, Los Angeles.

SciDAC

- The SciDAC program is aimed at improving the availability of and effective utilization of large scale computing. A major activity in the Technology category is developing tools to allow research scientists to more easily utilize currently available large scale computing resources.

  SciDAC funding is included in both the Physics Research category and the HEP Technology category (and a small amount is in the High Energy Physics Facilities subprogram). The total funding in FY 2003 in all categories is $4,410,000. The funding is distributed to a set of multiyear programs selected by peer review during FY 2001. These projects include work on tracking accelerator beams during the acceleration process, computing precise solutions to some of the fundamental equations of particle physics, development of systems to manage and analyze the very large quantities of data which are the routine output from the current generation of colliding beams detectors.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Physics Research	163,778	159,307	166,110	+6,803	+4.3%
High Energy Physics Technology	76,875	82,540	83,603	+1,063	+1.3%
SBIR/STTR	0	2,378	8,832	+6,454	+271.4%
Total, Research and Technology	240,653	244,225	258,545	+14,320	+5.9%

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Physics Research	**163,778**	**159,307**	**166,110**

Physics Research			
Universities	104,284	104,443	106,927
Fermilab	10,828	8,363	9,880
SLAC	12,755	12,930	13,082
BNL	10,989	10,316	10,391
LBNL	15,393	13,673	14,093
ANL	6,296	6,016	6,148
Other Physics Research	3,233	3,566	5,589
Total, Physics Research	163,778	159,307	166,110

▪ **Universities**	**104,284**	**104,443**	**106,927**

The university program consists of research groups at more than 100 universities doing experiments and theory. 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. The university groups usually work in collaboration with other university and laboratory groups. University based research efforts are selected based on peer review. The previous HEPAP Subpanel (1998), recommended that the level of funding for the university-based portion of the program be substantially increased over inflation over a two-year period. Due to budget constraints and other priorities, this has not been accomplished.

The university program is increased to provide support for those universities involved in the initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections. To the extent possible, the detailed funding allocations will take into account the involvement of university based research groups in the targeted physics research activities. These include research efforts related to the high priority experiments such as CDF, D-Zero, and BaBar, work on the design and fabrication of the LHC detector components, and research in support of U.S. participation in the LHC project.

These university based research activities are described in more detail below. The funding levels presented are estimates based on FY 2001 experience.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▸ **University Based Research at Fermilab**	**29,655**	**29,700**	**30,410**

Some 55 DOE-funded universities participate in large international collaborations doing experiments at Fermilab. These experiments include the CDF and D-Zero collider detectors, and the KTeV, MINOS, and Mini Boone experiments using external beams of kaons and neutrinos. Other experiments are performed in the antiproton accumulator. The experiments study the production and interaction of quarks and gluons as a probe for new particles such as the Higgs; search for evidence for the possible mass of the neutrino and for the transition of neutrinos among the various types; search for possible sources for the asymmetry of matter over antimatter in the universe, and a number of other topics. These universities help to fabricate the detectors, plan and execute the experiments, analyze data and publish the results. The emphasis of groups working at Fermilab is shifting as activity related to 800 GeV fixed target experiments is finished and activities related to Tevatron, MINOS, and other new experiments increase.

▸ **University Based Research at SLAC**	**12,340**	**12,360**	**12,650**

Some 22 DOE-funded universities participate in large international collaborations doing experiments at SLAC. The experiments involve the BaBar detector and other smaller detectors for fixed target experiments. In particular, the BaBar detector is being used to study the nature of CP violation in the B meson system. These universities help to build the detectors, plan and carry out experiments, analyze the data and publish the results.

▸ **University Based Research at BNL**..............................	**1,885**	**1,890**	**1,935**

Some seven DOE-funded universities have participated in collaborative experiments at BNL. These experiments involved fixed targets and kaon or pion beams, colliding beams of protons (RHIC-SPIN) or nuclei (PHOBOS) at RHIC, and an external storage ring measuring the muon anomalous magnetic moment to high precision.

▸ **University Based Research at Cornell**..........................	**4,300**	**4,310**	**4,410**

Some nine university High Energy Physics groups with DOE funding participate in the electron-positron colliding beam experiments at the Cornell Electron Storage Ring (CESR) facility utilizing the collaboratively built CLEO detector studying various aspects of B meson interactions and decay.

▸ **University Based Non Accelerator Research**	**10,400**	**10,415**	**10,665**

Some 34 DOE-funded universities are involved in supporting the High Energy Physics experiments not utilizing accelerators. The principal experiments being supported in FY 2003 are:

- The Cryogenic Dark Matter Search (CDMS) and Pierre Auger projects are currently being fabricated. A description of CDMS is under the Fermilab section and Auger is described under the Other Physics Research section, and the project funding is included there. The physicists working on these projects are included here in university based non-accelerator research.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

- The first phase of the Alpha Magnetic Spectrometer (AMS) experiment is complete and the data has been analyzed to obtain key information on the presence of antimatter in the cosmic radiation. The Detector is being upgraded for a second shuttle flight. The planned FY 2003 funding for this Major Item of Equipment (MIE) is $750,000 and the TEC for the DOE portion of the AMS upgrade is $4,756,000.
- The Very Energetic Radiation Imaging Telescope Array System (VERITAS) is a ground based high energy cosmic gamma ray detector designed to search for and study astrophysical gamma ray sources. As such, it will complement GLAST. It will be built at a site in Arizona with fabrication of the detector initiated in FY 2003. The VERITAS collaboration includes both U.S. and foreign university groups, and the funding is being provided approximately equally by NSF, the Smithsonian, and the DOE. The total planned expenditures for the DOE portion of VERITAS is estimated at about $6,000,000; the planned FY 2003 DOE funding is estimated at about $1,500,000.
- Other active experiments, which are primarily in the areas of high energy astrophysics and cosmology, include Super-Kamiokande (Japan), KamLAND (Japan), SNO (Canada), GRANITE (Mt. Hopkins, Arizona), and AXION (LLNL).

▸ **University Based Research at Foreign Labs**................	**17,915**	**17,940**	**18,370**

Universities funded by the DOE are doing experiments with international collaborations using facilities at foreign accelerator labs. Some 45 universities are conducting experiments at CERN (Switzerland), 11 at DESY (Germany), 10 at KEK (Japan), 1 at IHEP (Russia), 1 at BINP (Russia), and 2 at Beijing (China). This research addresses a wide range of fundamental questions such as the search for the Higgs boson, which may be a key to understanding the source of mass. The emphasis of university groups is shifting to the LHC research program at CERN/LHC and away from activities at DESY and the older programs at CERN.

▸ **University Research in Theory**......................................	**23,905**	**23,940**	**24,510**

Some 75 universities with DOE funding participate in research in theoretical high energy physics. Theoretical ideas, concepts, calculations and simulations of physical processes in high energy physics are a key to progress in that they provide guidance for the design of experiments and the basis for program priorities.

▸ **Other University Funding**	**3,884**	**3,888**	**3,977**

Primarily includes funding held pending completion of peer review of proposals that have been received, and funds to respond to new and unexpected physics opportunities. The Outstanding Junior Investigator program, that is intended to identify and provide support for highly promising investigators at an early stage in their careers, will continue at a level of about $400,000.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Fermilab**..........	**10,828**	**8,363**	**9,880**

In FY 2003, the experimental physics research groups at Fermilab will be focused mainly on data-taking with the upgraded CDF and D-Zero collider detector facilities, analysis of data taken in the FY 2002 collider run and the concluded 800 GeV fixed-target program, installation and commissioning of the MINOS detector, and fabrication of the CMS detector for the LHC. Also includes funding for work in theory and astrophysics.

The request includes funds to continue the Cryogenic Dark Matter Search (CDMS). The CDMS detector will use cryogenic techniques to search for weakly interacting massive particles (WIMPS). WIMPS are proposed as a possible explanation for the "missing" mass in the universe. CDMS is being done by a collaboration of universities and laboratories. The detector will be installed in the Soudan II underground laboratory in northern Minnesota. The planned FY 2003 funding for this Major Item of Equipment is $1,050,000 and the TEC for CDMS is $8,600,000.

The theoretical physics group will continue to emphasize topics related to the experimental physics programs as well as string theory and extra dimensions, lattice gauge theory, and Supersymmetry.

Funding is increased to provide additional support for the initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections.

▪ **SLAC**..........	**12,755**	**12,930**	**13,082**

The experimental physics research groups at SLAC will concentrate their efforts in FY 2003 on data taking and analysis of data from the BaBar detector operating with the B-factory accelerator facility. These data will be used to study CP violation in B meson decays, which may help explain the preponderance of matter over antimatter in the universe. The large BaBar dataset will provide many other forefront research results related to B meson decays. Fabrication of the Gamma Large Area Space Telescope (GLAST) will be a significant effort in FY 2003 in preparation for the launch projected to be in FY 2006. GLAST will study the very high energy cosmic rays reaching the earth before they have interacted in the atmosphere. Some physics research will also be done by fixed target experiments. The theoretical physics group will continue to emphasize topics related to BaBar and the other SLAC experimental physics programs as well as tests of the Standard Model, Quantum Chromodynamics (QCD) and Supersymmetry. **Performance will be measured** by progress toward the goal of describing and understanding CP Symmetry violation in the B meson system.

Funding is increased to provide additional support for the initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **BNL**	**10,989**	**10,316**	**10,391**

In FY 2003, the BNL experimental physics research groups will be primarily working on the D-Zero experiment, that will be taking data at Fermilab, and overseeing the fabrication of the U.S. portion of the ATLAS detector for the LHC. Data analysis for the precision measurement of the anomalous magnetic moment of the muon will be completed. The theoretical physics group will continue to emphasize topics related to the national experimental HEP program, including precision tests of the Standard Model, QCD and lattice gauge theories.

Funding is increased to provide additional support for the initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections.

▪ **LBNL**.........	**15,393**	**13,673**	**14,093**

In FY 2003, LBNL researchers will be focused on a number of research activities, including: data-taking with the CDF collider detector at Fermilab; data-taking with the BaBar detector at the B-factory storage ring at SLAC; data-analysis on the HYPER-CP experiment at Fermilab will be completed; and fabrication of the ATLAS detector, primarily the silicon tracking system, for the LHC, as well as development of the core software infrastructure for ATLAS. The researchers will also be working on supernova measurements to establish values of cosmological parameters. LBNL is involved in the SuperNova Acceleration Probe (SNAP) project to put in orbit a large infrared/optical telescope designed and instrumented to perform a precision measurement of the motion of Type Ia supernovae. The ultimate objective would be to determine whether the universe is accelerating outward in response to a fundamental new force, "dark energy." Funding ($400,000) is provided to support an R&D program to clarify the design, feasibility, and scientific capability of the proposed instrument. Additional funding ($980,000) is held as contingency pending further review of the progress of the challenging R&D presently underway. Funding is included for the Particle Data Group at LBNL, that continues as an international clearinghouse for particle physics information. The theoretical physics group will continue their research, that is strongly coupled to the LBNL experimental HEP program, including BaBar and ATLAS.

Funding is increased to provide additional support for the initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections.

▪ **ANL**	**6,296**	**6,016**	**6,148**

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 and installation of two major new detector facilities: the ATLAS detector for the 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.

Funding is increased to provide additional support for the initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Other Physics Research**	**3,233**	**3,566**	**5,589**

This activity includes funds to continue the Pierre Auger project. The Pierre Auger Project (Auger) is intended to detect and study very high energy cosmic rays using a very large array of surface detectors spread over 30,000 square kilometers. Auger is being done by a large international collaboration. The presently approved part of the project includes an array at a site in Argentina. The U.S. will provide only a small portion of the cost of the Argentine array. The total planned FY 2003 funding for this Major Item of Equipment is $1,140,000, of which $565,000 has been allocated to Fermilab. The TEC for the U.S. portion of this phase of the Auger project is $3,000,000.

The SuperNova Acceleration Probe (SNAP) project is intended to put in orbit a large infrared/optical telescope designed and instrumented to perform a precision measurement of the motion of Type Ia supernovae. The ultimate objective would be to determine whether the universe is accelerating outward in response to a fundamental new force, "dark energy." FY 2003 funding ($400,000) has been allocated to LBNL to support an R&D program to clarify the design, feasibility, and scientific capability of the proposed instrument. Additional FY 2003 funding ($980,000) is held as contingency pending further review of the progress of the challenging R&D presently underway.

This category also includes FY 2003 funding for smaller labs and other non-university performers ($2,306,000), conferences and workshops, studies, and research activities that have not yet completed peer review and programmatic decisions ($1,728,000).

High Energy Physics Technology..	**76,875**	**82,540**	**83,603**

High Energy Physics Technology			
Fermilab...	20,183	24,458	23,818
SLAC	22,333	24,280	24,810
BNL..	6,479	4,735	5,145
LBNL..	12,183	10,100	10,155
ANL..	2,479	2,005	2,005
Universities	9,638	9,736	9,980
Other Technology R&D...	3,580	7,226	7,690
Total, High Energy Physics Technology	76,875	82,540	83,603

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Fermilab**	**20,183**	**24,458**	**23,818**
▸ **Accelerator R&D**	**15,021**	**15,773**	**15,168**

The major focus of the Accelerator R&D program in FY 2003 will be the continuation of the effort to design and install modifications aimed at improving the luminosity (intensity) and operational efficiency of the Tevatron complex to aid in the search for the Higgs, etc. The planned improvements include improved beam focusing magnets, improvements to the RF beam acceleration and control systems, and improvements to the beam position monitors. Funding in the amount of $4,000,000 is included for support of this urgent R&D effort.

Other activities in FY 2003 include design of an electron cooling system to improve the quality of an antiproton beam processed through the recycler ring; R&D on superconducting RF cavities for a separated kaon beam; R&D on quadrupole magnets for the LHC interaction regions; and R&D to lay the technology foundations, long term, for possible future accelerators and experiments.

R&D on the NLC began formally at Fermilab in the first quarter of FY 2000 under a memorandum of understanding with SLAC. Funding will be at the same level as FY 2002 ($3,000,000). Fermilab has assumed the principal R&D responsibility for the two main linac beam lines, including accelerating structures, supports, and instrumentation and control. A major SLAC and Fermilab collaborative R&D activity is application of the Fermilab developed permanent magnet technology throughout the entire NLC beam optics chain. Fermilab is also responsible for applying their expertise in conventional civil construction to issues that could significantly reduce the NLC construction cost. There will also be an accelerator physics effort, in collaboration with SLAC, to more fully understand all aspects of the beam optics and beam transport for the NLC from the electron and positron sources to the electron-positron collision point.

Longer range R&D addresses the feasibility and design issues for muon storage rings/neutrino sources. Fermilab is lead laboratory for the muon cooling experiment, and LBNL is a major collaborator. This is a critical test issue for demonstrating the feasibility of ionization cooling in the muon storage ring context. Muon storage ring R&D is funded at about $890,000. Fermilab is also engaged in an advanced superconducting magnet and materials program (principally niobium tin) to develop magnetic optical elements for use in a muon storage ring/neutrino source and, in the very far term, a possible 100 TeV proton collider.

Funding is reduced slightly for Accelerator R&D. An increase was considered to be of less importance than continued support for the initiative to exploit the “window of opportunity” for exciting new physics results described in the introductory sections.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▸ **Experimental Facilities R&D**	**5,162**	**8,685**	**8,650**

R&D will continue on pixel silicon detectors, on a possible dedicated collider detector for studying B meson interactions (B-TeV); on photon veto systems for an experiment searching for rare decays of kaons; and on computing techniques and on specialized electronics to better process the high event rates seen and anticipated in the large detectors.

Funding is reduced slightly. An increase was considered to be of less importance than continued support for the initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections.

▪ **SLAC**	**22,333**	**24,280**	**24,810**
▸ **Accelerator R&D**	**21,390**	**23,215**	**23,790**

An important component of the FY 2003 SLAC program will be continuation of the accelerator R&D aimed at improving the luminosity and operational efficiency of the B-factory complex. Particular attention will be paid to finding ways to continue to improve the collision luminosity to an ultimate value of $3x10^{34}cm^{-2}s^{-1}$, an order of magnitude greater than the design value. The planned improvements include additional RF acceleration systems, improvements to the vacuum pumping system, and improvements to the beam control systems.

Activities in FY 2003 will include R&D on issues central to the design of the Next Linear Collider (NLC), an electron-positron colliding beam facility to operate in the 500 GeV to 1 TeV center-of-mass energy regime and upgradeable to 1.5 TeV. The R&D activity at SLAC will focus on understanding and overcoming limitations to achievable accelerating gradients, design and supporting engineering R&D on the electron and positron sources, damping rings, and connecting beam transport systems. Much of this work is done in collaboration with the Japanese laboratory for HEP, KEK. Technology development for the 11.4 GHz high-powered microwave sources that generate the power to accelerate electrons and positrons will continue with the goal of proving new, more cost effective technical approaches. Systems engineering, value engineering and risk analysis studies will be carried out to identify R&D opportunities to lower cost, exploit new technologies, and improve performance. The NLC R&D program at SLAC will be funded at $16,200,000 in FY 2003, the same as in FY 2002.

A program of general R&D into very advanced collider concepts will continue at a low level. This activity at SLAC will be closely coordinated with other participants in the high risk R&D program in advanced accelerator physics that is exploring the potential of lasers, plasmas, and ultra high frequency microwave systems to accelerate charged particles at ultra high gradients that is described in the introduction.

Funding is increased slightly for Accelerator R&D to allow continued support for the initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections.

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		
▸ **Experimental Facilities R&D**	**943**	**1,065**	**1,020**

In FY 2003, the emphasis will be on work to support and improve performance of BaBar, the newly operating B-factory detector, and a modest program of R&D, on developing preliminary designs for a detector to operate with a possible new electron-positron linear collider operating at the TeV center of mass energy scale. Funding in the amount of $250,000 is included for R&D related to the upgrade of the BaBar detector.

Funding is reduced slightly. An increase was considered to be of less importance than continued support for the initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections. With no increase, the level of research activity will decrease due to the impact of inflation.

	FY 2001	FY 2002	FY 2003
▪ **BNL**	**6,479**	**4,735**	**5,145**
▸ **Accelerator R&D**	**5,466**	**3,795**	**4,205**

Activities in FY 2003 will include, R&D on new methods of particle acceleration such as laser acceleration and inverse free electron laser (IFEL) accelerators, primarily using the excellent capabilities of the BNL Accelerator Test Facility.

BNL also has a major involvement in muon storage ring R&D, primarily in the area of the muon production target and collection systems. This target/capture R&D is critical for demonstrating the feasibility of a muon storage ring. This funding is increased by $39,000 to $1,064,000.

The BNL superconductor test facility will be used to study the characterization of new high critical temperature superconductors as well as the special requirements for high field magnet fabrication. The program for testing of superconducting cable for LHC magnets will continue.

Funding is increased by $371,000 to partially offset the impact of inflation.

	FY 2001	FY 2002	FY 2003
▸ **Experimental Facilities R&D**	**1,013**	**940**	**940**

In FY 2003, semiconductor drift photo diodes for detection of photons of energies as low as 50 eV will be designed and produced. Development of radiation hardened monolithic electronics for a number of experiments will continue. Development of lead-tungstate crystals with improved light output will continue. Testing of the modules that constitute the ATLAS barrel calorimeters will continue.

Funding for this activity is held flat in order to exploit the "window of opportunity" for exciting new physics results described in the introductory sections. With no increase, the level of research activity will decrease due to the impact of inflation.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **LBNL**	**12,183**	**10,100**	**10,155**
▸ **Accelerator R&D**	**10,065**	**8,130**	**8,185**

The high-gradient, all-optical, laser-plasma wakefield accelerator at LBNL will begin accelerating electron bunches in preparation for a series of experiments in novel acceleration techniques and their application to high-intensity positron sources.

LBNL is a major contributor to accelerator and superconducting magnet R&D for advanced accelerator concepts, including the muon storage ring and the next linear collider. Development of these concepts is needed to advance the energy and luminosity frontiers to better understand the structure of matter. In FY 2003, preparations for muon cooling experiments to be performed at Fermilab, needed to confirm the practicality of a muon storage ring, will continue, using components fabricated at LBNL. Funding for this activity is increased by $5,000 relative to FY 2002 to $280,000 in FY 2003.

▸ **Experimental Facilities R&D**	**2,118**	**1,970**	**1,970**

LBNL has an industry forefront capability for designing and producing custom state-of-the-art electronics, such as silicon vertex detectors, integrated circuit (IC) systems, and other components for high energy particle detectors such as BaBar at the B-factory and the upgrades to CDF and D–Zero for the next, higher luminosity, runs at Fermilab. LBNL is also involved in developing computer programs for experimental data taking and analysis. In FY 2003, work will continue on large area charge-coupled devices and high-resolution imaging systems, plus the production and testing of IC systems.

Funding for this activity is held flat in order to exploit the "window of opportunity" for exciting new physics results described in the introductory sections. With no increase, the level of research activity will decrease due to the impact of inflation.

▪ **ANL**	**2,479**	**2,005**	**2,005**
▸ **Accelerator R&D**	**1,575**	**1,160**	**1,160**

R&D will continue on the acceleration of electrons using structures with plasmas or structures made of dielectric materials called wakefield accelerators. Researchers have achieved predicted accelerating gradients at encouraging levels using this new technique. Results are expected in obtaining high accelerating gradients with greatly enhanced beam stability using dielectric structures, and planning is underway for an upgraded experimental capability to generate much higher accelerator gradients using plasmas in structures driven by intense bunches of electrons. Related theoretical work will also continue.

Funding for this activity is held flat in order to exploit the "window of opportunity" for exciting new physics results described in the introductory sections. With no increase, the level of research activity will decrease due to the impact of inflation.

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		
▸ **Experimental Facilities R&D**	**904**	**845**	**845**

In FY 2003 work will be underway on the MINOS detector, the ATLAS detector for the LHC, and an upgrade of the ZEUS detector at DESY.

Funding for this activity is held flat in order to exploit the "window of opportunity" for exciting new physics results described in the introductory sections. With no increase, the level of research activity will decrease due to the impact of inflation.

	FY 2001	FY 2002	FY 2003
▪ **Universities**	**9,638**	**9,736**	**9,980**

The funding will provide for a program of high priority technology R&D at about 20 universities 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; muon storage rings; 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. University based research efforts will be selected based on review by appropriate peers.

Funding is increased slightly to continue support for the initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections.

	FY 2001	FY 2002	FY 2003
▪ **Other Technology R&D**	**3,580**	**7,226**	**7,690**

This category includes funding ($1,987,000) for R&D at a number of smaller DOE labs and other non-university sites on several of the topics described. This funding is increased slightly ($+71,000). This R&D effort is primarily a part of the high risk R&D described in the Mission Supporting Goals and Objectives – Technology R&D discussion. 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 category also includes $1,264,000 held as contingency for muon storage ring/neutrino source challenging R&D. Most of the muon storage ring/neutrino source funding has been allocated to the participating laboratories. The total funding for Muon Storage Ring in FY 2003 is $3,563,000 which is decreased by $2,226,000 from FY 2002.

Funding for Other Technology R&D activities that have not been allocated pending completion of peer review or program office detailed planning is included at $4,439,000 an increase of $1,873,000.

	FY 2001	FY 2002	FY 2003
SBIR/STTR	**0**	**2,378**	**8,832**

Includes $1,512,000 for the SBIR program and $866,000 for the STTR program in FY 2002 and $7,947,000 for the SBIR program and $885,000 for the STTR program in FY 2003. This is partially offset by a decrease for the SBIR program in the High Energy Physics Facilities subprogram.

	FY 2001	FY 2002	FY 2003
Total, Research and Technology	**240,653**	**244,225**	**258,545**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
▪ **Physics Research**	
► In University Physics Research, an increase of $2,484,000 to assist participation in the high priority experiments at Fermilab and SLAC	+2,484
► In Physics Research at Fermilab, an increase of $1,517,000 to assist with physics studies and data analysis from the high priority Higgs search	+1,517
► In Physics Research at SLAC, an increase of $152,000 to partially offset the impact of inflation.	+152
► In Physics Research at BNL, an increase of $75,000 to assist participation in the high priority experiments at Fermilab.	+75
► In Physics Research at LBNL, an increase of $420,000 to assist participation in the high priority experiments at Fermilab and SLAC.	+420
► In Physics Research at ANL, an increase of $132,000 to assist participation in the high priority experiments at Fermilab.	+132
► In Other Physics Research, an increase of $135,000 in funding for small labs and other non-university participants; a decrease of $565,000 in funds held as contingency for the Auger project ($565,000 has been allocated to Fermilab); a decrease of $189,000 in funds held as contingency for the SciDAC program; and an increase of $2,642,000 in the funds held pending completion of peer review and programmatic consideration.	+2,023
Total, Physics Research	+6,803
▪ **High Energy Physics Technology**	
► Technology R&D activities at Fermilab decrease $640,000 reflecting decreases of $790,000 in muon collider R&D and of $35,000 in Experimental Facilities R&D offset by an increase of $185,000 in funding for general accelerator R&D.	-640
► Technology R&D activities at SLAC increase $530,000 to partially offset the impact of inflation.	+530
► Technology R&D activities at BNL increase $410,000 to offset the impact of inflation and assist with operation of the Accelerator Test Facility.	+410
► Technology R&D activities at LBNL increase $55,000 to partially offset the impact of inflation..	+55
► In Technology R&D at Universities, an increase of $244,000 to partially offset the impact of inflation.	+244

	FY 2003 vs. FY 2002 ($000)
▸ In Other Technology R&D, an increase of $71,000 for funding at small labs and other non-university sites and an increase of $1,873,000 in funding held as contingency pending the completion of peer review and program office considerations and a reduction to muon collider R&D for higher priority activities of $1,480,000.	+464
Total, High Energy Physics Technology	+1,063

- **SBIR/STTR**

▸ An increase of $6,454,000 in the SBIR/STTR allocations. This is partially offset by a decrease in High Energy Physics Facilities of $5,596,000 for SBIR.	+6,454
Total Funding Change, Research and Technology	+14,320

The following table displays funding in High Energy Physics for R&D on possible future HEP facility concepts:

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Next Linear Collider	19,157	19,200	19,200
Muon Storage Ring/Neutrino Source	5,445	5,789	3,563

High Energy Physics Facilities

Mission Supporting Goals and Objectives

The program will operate and improve its existing research facilities to ensure efficiency, effectiveness, and safety. The Tevatron data rate will increase by a factor of 2-5 by FY 2005. The B-factory will continue to accumulate substantial data on a range of heavy quark physics topics, with special emphasis on the asymmetry between matter and antimatter in the universe.

The United States will execute its long-range strategy for high energy physics facilities, with important input and consensus from the 20-year "roadmap" submitted by the High Energy Physics Advisory Panel (HEPAP) to DOE and NSF in 2002.

During the next five years, the program will meet its commitments to the accelerator and detector components of the Large Hadron Collider (LHC) facility now under construction. It will participate fully in the research program when the LHC begins operations at CERN, planned for 2006.

During the next five years, NuMI/MINOS will be completed and begin accumulating data, which will be analyzed to answer fundamental questions about the neutrino—whether it has mass and transforms ("oscillates") from one type to another.

Resources provided by the Scientific Discovery through Advanced Computing (SciDAC) initiative will be used to support access to and manipulation of the massive data flows from high energy physics research facilities.

The High Energy Physics Facilities subprogram includes the provision and operation of the large accelerator and detector facilities, the essential tools that enable scientists in university and laboratory based research groups to perform experimental research in high energy physics.

The FY 2003 program described earlier contains the following facility operation elements.

- Full operation of the Tevatron at Fermilab and the B-factory at SLAC for the research program planned at those facilities. This includes operation of the accelerators and storage rings, and operation of the ancillary and support facilities including in particular the computing facilities. The Alternating Gradient Synchrotron is terminated for High Energy Physics research in FY 2003.
- Continuation of the planned program of upgrades for the Tevatron and the B-factory. The physics goals of the HEP program described earlier (detection of Higgs; study of CP Violation, etc.) require a substantial amount of data collection. Facility upgrades that increase the beam intensity and detector efficiency are extremely important since they increase the data collection rate just as effectively as does additional operation. The data collection goals needed to achieve the physics objectives require both extended running and an ongoing program of facility and detector upgrades.
- Continued work on the agreed to components and subsystems for the LHC accelerator and detectors.
- Site infrastructure maintenance and improvement. The High Energy Physics Facilities subprogram includes general plant projects (GPP) funding (at Fermilab, SLAC and LBNL) and general purpose equipment (GPE) funding (at LBNL).

The principal objective of the High Energy Physics Facilities subprogram is to maximize the quantity and quality of data collected for approved experiments being conducted at the High Energy Physics facilities. The ultimate measure for success in the High Energy Physics Facilities subprogram is whether the research scientists have data of sufficient quantity and quality to do their planned measurements. 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.

	(in weeks)		
	FY 2001	FY 2002	FY 2003
Fermilab	22	39	39
SLAC[a]	34	35	39
BNL	19	16	0

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Fermi National Accelerator Lab	219,388	244,535	239,042	-5,493	-2.2%
Stanford Linear Accelerator Center	119,226	127,335	125,995	-1,340	-1.1%
Brookhaven National Laboratory	6,014	5,725	0	-5,725	--
Other Support	19,447	18,032	14,518	-3,514	-19.5%
Large Hadron Collider	58,870	49,000	60,000	+11,000	+22.4%
SBIR/STTR	0	12,918	6,797	-6,121	-47.4%
Total, High Energy Physics Facilities	422,945	457,545	446,352	-11,193	-2.4%

[a] The number of weeks is projected on the basis of the continuing availability of electrical power at affordable prices, an assumption that may be questionable in California.

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Fermilab	**219,388**	**244,535**	**239,042**

Provides support for operation, maintenance, improvement, and enhancement of the Tevatron accelerator and detector complex and for maintenance of the laboratory physical plant. This complex includes the Tevatron, that can operate in a collider mode with protons and antiprotons, or in a fixed target mode with protons only; the Main Injector that was completed and commissioned in FY 1999 and is fully operational; the Booster; the Linac; and the Antiproton Source and Accumulator. The Tevatron collider and the 800 GeV fixed target modes are mutually exclusive, and no 800 GeV fixed-target running is planned in the foreseeable future; however, a fixed target program at 120 GeV using the new Main Injector is possible in parallel with Tevatron collider operation.

Tevatron operation in FY 2003 will be focused on an extended run to collect the maximum amount of data for the physics goals (Higgs, etc.) described earlier. This will include full operation of the two large detectors, CDF and D-Zero, and the supporting computing facilities. The Tevatron will operate for about 39 weeks in FY 2003. **Performance will be measured by** adherence to planned running schedules and by progress on maintaining and enhancing luminosity and operational efficiency for the Tevatron at Fermilab in its new mode of operation with the new Main Injector.

▪ **Operations**	**188,809**	**198,230**	**194,757**

Operations at Fermilab will include operation of the Tevatron in collider mode for about 39 weeks. This will be a major physics run with the higher intensity available from the new Main Injector and with the newly upgraded D-Zero and CDF detectors. This is to be a major data collection period for the experiments searching for the Higgs and related phenomena as described in more detail earlier.

The funding provided will support the planned Tevatron operation and will assist with installation and commissioning of planned luminosity upgrades.

Tevatron Operation

	(in weeks)		
	FY 2001	FY 2002	FY 2003
Tevatron Operation	22	39	39

▪ **Support and Infrastructure**	**30,579**	**46,305**	**44,285**

Funding in the amount of $25,500,000 (Capital Equipment - $19,000,000; AIP - $6,500,000) is included for the program to increase the Tevatron luminosity, upgrade the CDF and D-Zero detectors, and provide the computing capability needed to analyze the data collected. This is all aimed at exploiting the "window of opportunity" described above. This is an increase of $11,580,000 (Capital Equipment +$12,080,000; AIP -$500,000) over FY 2002 and includes continuation of the two Major Items of Equipment projects involving the replacement of the Silicon Tracker Subsystems with new state-of-the-art radiation-hard silicon for both the CDF Detector ($7,500,000; TEC of $15,000,000) and D-Zero Detector ($7,500,000; TEC of $15,000,000). Also included is $4,000,000 for smaller projects needed for the upgrades. The increased funding for the

	(dollars in thousands)	
FY 2001	FY 2002	FY 2003

machine and detector upgrades reflects the high priority given to the highly effective operation of the Tevatron for the physics goals and are aimed at improving the luminosity and efficiency of operation of the Tevatron. The Silicon Tracker Subsystem replacements will be necessary since in the normal course of operation the silicon in the detectors gets damaged by radiation and needs to be replaced. The technology involving radiation-hard silicon has improved significantly since the design for the last upgrades to the detectors was completed five years ago. This will allow these detector subsystems to better withstand the higher intensities needed in the search for the Higgs.

Capital Equipment for the MINOS Detector, a Major Item of Equipment, is included at $5,490,000. This is reduced from FY 2002 by $9,785,000 following the revised funding profile and is consistent with the NuMI project completion date. MINOS is the detector part of the NuMI project that will provide a major new capability for neutrino research. Capital Equipment for other laboratory needs is reduced (-$3,155,000) to $6,495,000. AIP for other laboratory needs is reduced from FY 2002 (-$660,000) to $2,000,000.

GPP funding is unchanged at $4,800,000 to address urgent ES&H and infrastructure needs at the lab.

	FY 2001	FY 2002	FY 2003
SLAC	**119,226**	**127,335**	**125,995**

Provides for the operation, maintenance, improvement and enhancement of the accelerator and detector complex on the SLAC site. The accelerator facilities include the electron linac, the B-factory, completed in FY 1999, and the NLC Test Accelerator. The B-factory is fully operational and is performing well. The detector facilities include BaBar, the detector for the B-factory, the End Station A experimental set-ups, and the Final Focus Test Beam. This will be a major data collection period for the experiment studying the B meson system and the phenomenon of CP Violation as described earlier.

B-factory operation in FY 2003 will be focused on an extended run to collect the maximum amount of data for the physics goals described earlier. This will include full operation of the large detectors – BaBar – and the supporting computing facilities. The B-factory will operate for about 39 weeks in FY 2003. **Performance will be measured by** adherence to planned running schedules and progress on achieving and increasing luminosity and operational efficiency for the B-factory at SLAC as measured by comparison with stated project goals.

Also provides for the fabrication of the GLAST detector, which is to be a satellite-based study of high energy gamma rays in the cosmic radiation.

Also provides for maintenance of the laboratory physical plant.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Operations**..	**94,971**	**100,890**	**97,275**

The funding will provide operations at SLAC in FY 2003 for about 39 weeks of strong utilization of the asymmetric B-factory colliding beam storage rings to maximize the data collected by the BaBar detector facility, and for corresponding support of detector operations and computing operations. This will be the priority research program at SLAC in FY 2003. This will be supplemented by a modest (8 weeks) fixed target research program in End Station A that will be run in parallel with B-factory operation. The linac will serve as the injector of positrons and electrons to the B-factory storage rings during this time.

SLAC Operation

	(in weeks)		
	FY 2001	FY 2002	FY 2003
Fixed Target[a]...	8	8	8
B-factory Operation..	34	35	39
Total, SLAC Operation..	34	35	39

▪ **Support and Infrastructure**..	**24,255**	**26,445**	**28,720**

Funding for the projects to upgrade the B-factory, the BaBar detector, and the SLAC computing facilities needed to process the BaBar data is included at $11,800,000 (Capital Equipment $4,200,000; AIP $7,600,000). Capital equipment funding for the GLAST Major Item of Equipment, the large gamma ray detector designed to study cosmic gamma rays from a satellite, is increased by $830,000 to $8,910,000. GLAST is a joint DOE-NASA project aimed at studying gamma rays in the cosmic radiation using a satellite-based instrument; the TEC is $35,000,000. Funding for other Capital Equipment needs is included at $1,120,000. Funding for other AIP is included at $2,690,000 (up from $800,000 in FY 2002) to assist in maintaining the operational efficiency of the B-factory and its injection system. Funding for GPP is held constant at $4,200,000 to address urgent ES&H and infrastructure needs.

BNL...	**6,014**	**5,725**	**0**

Provides support for the HEP related operation, maintenance, improvement, and enhancement of the AGS complex at BNL and its complement of experimental set ups. The AGS is operated by the Nuclear Physics program as part of the RHIC facility and operation of the AGS for the HEP program has been on an incremental cost basis. The AGS will not be operated for the HEP physics experiments in FY 2003.

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

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Operations**	**5,634**	**5,630**	**0**

Funding provided for the incremental cost of running the AGS complex for HEP in FY 2001 and FY 2002. There will be no operation of the AGS for High Energy Physics experiments in FY 2003.

AGS Operation

	(in weeks)		
	FY 2001	FY 2002	FY 2003
AGS Operation for HEP	19	16	0

▪ **Support and Infrastructure**	**380**	**95**	**0**

Includes capital equipment funding for HEP use of the AGS in FY 2001 and FY 2002. There will be no operation of the AGS for High Energy Physics experiments in FY 2003.

Other Support	**19,447**	**18,032**	**14,518**

Full and effective participation by U.S. scientists in the LHC research program (the LHC is scheduled to begin operation in 2006) requires an effective system to make the data recorded by the detectors at CERN available for analysis by participating scientists at U.S. universities and laboratories. This problem is compounded by the enormous magnitude of the amount of data that will be recorded. This category includes funding for continuing the design, implementation, and operation of the computing facilities and network links needed to process, store, and analyze this large body of data. The total funding for LHC computing support is $5,730,000 which is increased by $2,040,000 from FY 2002.

Full and effective participation by U.S. scientists in the LHC research program also requires support for the preparation for operation of the two large detectors in which U.S. scientists are major collaborators. The nature and magnitude of these costs is under active discussion with CERN and the international collaborations that have overall responsibility for the detectors. Preliminary estimates are $300,000 in FY 2002 and $1,000,000 in FY 2003.

This category also includes $135,000 for the SciDAC program. Total funding in the HEP program for this activity is $4,410,000 which is decreased by $510,000 from FY 2002.

This category also includes $1,950,000 (-$147,000) for General Purpose Equipment and $3,500,000 (+$458,000) for General Plant Projects at LBNL. The combined funding at LBNL increases by $311,000.

This category also includes funding ($2,203,000) for a number of small activities including computer networking and funds held in reserve pending completion of peer review and programmatic consideration. These funds are decreased substantially (-$6,700,000) to support higher priority activities.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Large Hadron Collider	**58,870**	**49,000**	**60,000**

The funding requested follows the currently approved profile which is revised from the original profile. Changes have been made to better match the funding profile to the funding needs of (1) the three U.S. projects based on their current fabrication plans and schedules, (2) the updated LHC construction schedule as determined by CERN, and (3) to reflect CERN's updated billing profile for payments under the "Procurements from U.S. Industry" program. This funding will allow the project to continue on the revised approved CERN schedule and will not affect the planned completion date or the total cost of the U.S. projects and the LHC itself.

Construction and technical difficulties on the CERN site have led to delays in the project. These problems are being overcome and the latest official CERN schedule shows approximately a nine-month slippage with first collisions in April 2006. This schedule slippage is being accommodated in the planning for the U.S. LHC projects with minimal impact on schedule and no increase in total cost to the U.S.

The CERN managed LHC project overall has undergone a cost growth on the order of twenty percent. CERN management is moving aggressively to reduce costs and to establish a solid plan for completing the LHC. This plan is being developed, and is expected to be completed and approved by June 2002. The U.S. position is that the DOE and NSF contributions will not be increased in response to the CERN cost growth problem.

The European Center for Nuclear Research (CERN) in Geneva, Switzerland initiated the Large Hadron Collider (LHC) project in FY 1996. 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. Completion of the LHC is projected for 2006.

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 when it begins operations in 2006. With the LHC at the next energy frontier, American scientific research at that frontier depends on participation in LHC. The High Energy Physics Advisory Panel (HEPAP) Subpanel on Vision for the Future of High Energy Physics (Drell) strongly endorsed participation in the LHC, and this endorsement has been restated by HEPAP on several occasions.

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

(dollars in thousands)		
FY 2001	FY 2002	FY 2003

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

Participation in the LHC project (accelerator and detectors) at CERN primarily takes 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 goes to U.S. laboratories, university groups, and industry for fabrication of subsystems and components that will become part of the LHC accelerator or detectors. A portion of the funds is being used to pay for purchases by CERN of material needed for construction of the accelerator 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 2005 (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.

U.S. LHC Accelerator and Detector Funding Profile

(dollars in thousands)

Fiscal Year	Department of Energy			National Science Foundation[a]
	Accelerator	Detector	Total	
1996[b]	2,000	4,000	6,000	0
1997[b]	6,670	8,330	15,000	0
1998[b]	14,000	21,000	35,000	0
1999	23,491	41,509	65,000	22,150
2000	33,206	36,794	70,000	15,900
2001	27,243	31,627	58,870	16,370
2002	21,303	27,697	49,000	16,860
2003	22,100	37,900	60,000	9,720
2004	29,330	30,670	60,000	0
2005	20,657	10,473	31,130	0
Total	200,000[c]	250,000	450,000	81,000

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

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

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

LHC Accelerator and Detector Funding Summary

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
High Energy Physics Facilities			
LHC			
Accelerator Systems			
Operating Expenses	1,098	1,900	1,850
Capital Equipment	18,068	8,196	6,850
Total, Accelerator Systems	19,166	10,096	8,700
Procurement from Industry	8,077	11,207	13,400
ATLAS Detector			
Operating Expenses	8,919	3,594	7,282
Capital Equipment	5,556	6,913	10,134
Total, ATLAS Detector	14,475	10,507	17,416
CMS Detector			
Operating Expenses	10,785	11,190	12,482
Capital Equipment	6,367	6,000	8,002
Total, CMS Detector	17,152	17,190	20,484
Total, LHC	58,870	49,000	60,000

In FY 2003, funding will be used for the fabrication of accelerator magnets and equipment and the R&D, prototype development, and fabrication of detector subsystems such as tracking chambers, calorimeters, and data acquisition electronics.

The LHC work is being performed at various locations including 4 DOE laboratories and 60 U.S. universities.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Accelerator Systems**	**19,166**	**10,096**	**8,700**

In FY 2003, funding will support continued production of quadrupole magnets, cryogenic/electrical power feedboxes, and beam absorbers for the LHC beam interaction regions. Production of dipole magnets for the interaction and radio-frequency regions will be completed. Production testing of superconducting wire and cable for the LHC main magnets will continue at peak rates. Accelerator physics calculations will continue. Funding is reduced by $1,396,000 as production activities begin to ramp down.

▪ **Procurement from Industry**	**8,077**	**11,207**	**13,400**

In FY 2003, funding will continue to support reimbursement to CERN for purchases from U.S. industry including superconducting wire, cable, cable insulation materials, and other technical components. This figure reflects the latest information on the planned expenditure profile. Funding is increased by $2,193,000 to support the current estimate of actual invoices from U.S. industrial suppliers which are expected to peak in 2004.

▪ **ATLAS Detector**	**14,475**	**10,507**	**17,416**

In FY 2003, funding will support continued production of detector hardware and electronics and the installation of U.S.-supplied equipment at CERN. Production of the transition radiation tracker mechanics will be completed and the production of the inner tracker will continue. The delivery to CERN of monitored drift tubes chambers and various components of the liquid argon calorimeter will continue. The last tile calorimeter components will be shipped to CERN. Fabrication of the detector trigger and data acquisition system will begin. Funding is increased by $6,909,000 to support peak production rates for detector components. Funding will ramp down in subsequent years.

▪ **CMS Detector**	**17,152**	**17,190**	**20,484**

In FY 2003, funding will support continued production of detector hardware and electronics and the assembly and installation of U.S.-supplied equipment at CERN. Assembly of the hadron calorimeter will continue at CERN in parallel with the production of final electronics and readout boxes. Endcap muon chambers will be delivered to CERN, production of electronics for the electromagnetic calorimeter and the mechanics for the inner tracker will continue. Final tests of prototype hardware for the trigger will be completed. Funding is increased by $3,294,000 to support peak production rates for detector components. Funding will ramp down in subsequent years.

SBIR/STTR	**0**	**12,918**	**6,797**

In FY 2001, $14,409,000 was transferred to the SBIR program and $865,000 was transferred to the STTR program. This section includes $12,918,000 in FY 2002 and $6,797,000 in FY 2003 for the SBIR program. The balance of the SBIR and the STTR allocations are included in the Research and Technology subprogram.

Total, High Energy Physics Facilities	**422,945**	**457,545**	**446,352**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
▪ **Fermilab**	
► A decrease of $3,473,000 in Operations results primarily from completion of site preparation for MINOS at the Soudan site	-3,473
► Increases in Capital Equipment totaling $8,080,000 for the two detector upgrade projects, and an increase of $4,000,000 for additional computer hardware needed to take advantage of major scientific opportunities	+12,080
► A decrease of $9,785,000 for MINOS consistent with revised project profile and the NuMI construction schedule, and a decrease of $3,155,000 in other laboratory equipment. This decrease is partially offset by an increase of $8,693,000 for NuMI construction shown in the Construction section.	-12,940
► Accelerator Improvement Project (AIP) funding is reduced by $500,000 related to the planned upgrade. AIP funding for other projects is reduced by $660,000.	-1,160
Total, Fermilab.	-5,493
▪ **Stanford Linear Accelerator Center**	
► A decrease of $3,615,000 in Operations. This primarily reflects funds shifted to AIP in order to obtain of a better balance between operation of the B-factory and support for the high priority program of upgrading the machine and detector.	-3,615
► An increase of $2,275,000 consisting almost entirely of an increase in AIP funding related to planned luminosity increases	+2,275
Total, Stanford Linear Accelerator Center	-1,340
▪ **Brookhaven National Laboratory**	
► At BNL, a decrease of $5,725,000 reflecting termination of the AGS for HEP research.	-5,725
Total, Brookhaven National Laboratory	-5,725

	FY 2003 vs. FY 2002 ($000)
▪ **Other Support**	
▸ The landlord funding at LBNL (GPP and GPE) is increased by $311,000. Funding held in reserve for the SciDAC program is increased by $135,000. The funding to establish a data handling system for the LHC data is increased by $2,040,000. Funding for pre-operations of the LHC detectors is increased by $700,000. Other funding, including funds held in reserve pending completion of peer review and program office considerations, is decreased by $6,700,000.	-3,514
▪ **Large Hadron Collider**	
▸ A increase of $11,000,000 reflecting the revised approved expenditure profile	+11,000
▪ **SBIR/STTR**	
▸ A decrease of $6,121,000 in funding for SBIR. This reflects a shift in funding to Research and Technology for the SBIR program.	-6,121
Total Funding Change, High Energy Physics Facilities	-11,193

The following table shows the details of the funding for the GLAST and MINOS projects.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
GLAST (SLAC Capital Equipment)	5,192	8,080	8,910
GLAST (University Capital Equipment)	497	0	0
Total	5,689	8,080	8,910
MINOS			
Operating	3,000	3,725	224
Capital Equipment	11,974	15,275	5,490
Total	14,974	19,000	5,714

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 2001	FY 2002	FY 2003	$ Change	% Change
Neutrinos at the Main Injector	22,949	11,400	20,093	+8,693	+76.3%
Wilson Hall Safety Improvement Project	4,191	0	0	0	--
SLAC Research Office Building	5,189	0	0	0	--
Total, Construction	32,329	11,400	20,093	+8,693	+76.3%

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Neutrinos at the Main Injector (NuMI)**	**22,949**	**11,400**	**20,093**

This project provides for the construction of new facilities at Fermilab and at the Soudan Underground Laboratory in Soudan, Minnesota that are specially designed for the study of the properties of the neutrino and in particular to search for neutrino oscillations. The FY 2003 funding is for construction and installation of the neutrino beam line in the underground tunnel, and for construction of the surface buildings at Fermilab.

The project has encountered serious problems in several areas resulting in an increase of $33,093,000 in the project TEC and a schedule slip of two years. Due to a tight market for civil construction, the cost for excavating tunnels and halls at the Fermi National Accelerator Laboratory (Fermilab) is considerably higher than the initial estimate. Rebidding this subcontract to reduce its cost entailed a significant delay, as has the subsequent performance of the work. The contractor boring the tunnel for the neutrino production beam has encountered problems with the startup of the tunnel boring machine. This has led to a significant delay. Treatment and disposal of the ground water flowing into the tunnel is requiring significant effort. The experiment requires an extremely high intensity proton beam to produce an adequate number of neutrinos. The shielding required to suppress the secondary radioactivity has turned out to be significantly more extensive than originally planned, and the radiation levels near the target station will require a significant remote handling capability for routine operation and maintenance.

	FY 2001	FY 2002	FY 2003

(dollars in thousands)

The MINOS detector for NuMI, funded as part of the Other Project Costs, is proceeding well, and completion is expected within the revised projected cost and schedule.

Because of these developments, the project costs have risen. The TPC is increased to $171,442,000 from the previously approved $139,390,000, and the TEC is increased to $109,242,000 from the previously approved $76,149,000. The completion is delayed by about two years to the end of FY 2005. **Performance will be measured** by accomplishment of scheduled milestones as detailed in the revised benchmark plan.

	FY 2001	FY 2002	FY 2003
▪ **Wilson Hall Safety Improvement Project (Fermilab)**.....	**4,191**	**0**	**0**

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. Funding was completed in FY 2001 and the project is on schedule for completion in FY 2002. **Performance will be measured** by the total cost at completion and by the completion date.

	FY 2001	FY 2002	FY 2003
▪ **SLAC Research Office Building**	**5,189**	**0**	**0**

This project provides urgently needed office space for the substantial expansion of visiting scientists, or "users," resulting from the B-factory becoming operational. The visiting user population is projected to increase from 200 visitors per year to 1,100 visitors per year. The new building will provide about 30,000 square feet and is on schedule for completion at the end of FY 2001. **Performance will be measured** by the total cost at completion and by the completion date.

	FY 2001	FY 2002	FY 2003
Total, Construction..	**32,329**	**11,400**	**20,093**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
▪ **Neutrinos at the Main Injector (NuMI)**	
▸ Provides for completion of the Fermilab NuMI project on the revised profile. Reflects the increased project TEC described above.	+8,693
Total Funding Change, Construction	+8,693

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
General Plant Projects	10,292	12,042	12,500	+458	+3.8%
Accelerator Improvements Projects	11,069	17,660	18,790	+1,130	+6.4%
Capital Equipment	83,383	84,476	83,831	-645	-0.8%
Total, Capital Operating Expenses	104,744	114,178	115,121	+943	+0.8%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2001	FY 2002	FY 2003	Unapprop-riated Balance
98-G-304 Neutrinos at the Main Injector	109,242	41,800	22,949	11,400	20,093	13,000
99-G-306 Wilson Hall Safety Improvements	15,591	11,400	4,191	0	0	0
00-G-307 SLAC Research Office Building	7,189	2,000	5,189	0	0	0
Total, Construction		55,200	32,329	11,400	20,093	13,000

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2001	FY 2002	FY 2003 Request	Accept-ance Date
D-Zero Upgrade	61,208	56,912	4,296	0	0	FY 2001
Large Hadron Collider — Machine	85,972	46,438	18,068	8,196	6,850	FY 2005
Large Hadron Collider — ATLAS Detector	56,113	21,200	5,556	6,913	10,134	FY 2005
Large Hadron Collider — CMS Detector	65,057	35,538	6,367	6,000	8,002	FY 2005
MINOS[a]	44,510	9,271	11,974	15,275	5,490	FY 2005
GLAST [b]	35,000	3,000	5,689	8,080	8,910	FY 2005
Cryogenic Dark Matter Search (CDMS)	8,600	800	1,798	1,050	1,050	FY 2007
Auger	3,000	0	0	1,140	1,140	FY 2004
Alpha Magnetic Spectrometer (AMS) Upgrade [c]	4,756	1,000	1,228	1,778	750	FY 2003
D-Zero Silicon Tracker Replacement[d]	15,000	0	0	3,460	7,500	FY 2005
CDF Silicon Tracker Replacement[d]	15,000	0	0	3,460	7,500	FY 2005
Total, Major Items of Equipment		174,159	54,976	55,352	57,326	

[a] Reflects recently approved baseline revision.

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

[c] A change in the assignment of responsibilities within the international AMS collaboration has been agreed to by DOE. This results in an expanded scope for the U.S. portion of AMS and an increase of $1,728,000 in the TEC of the DOE portion of the project.

[d] These upgrade projects are only in an advanced planning stage. Thus changes to the TEC and the profile may be needed.

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

(Changes from FY 2002 Congressional Budget Request are denoted with a vertical line [|] in the left margin.)

Significant Changes

The Total Project Cost (TPC) has been adjusted due to an increase in the Total Estimated Cost (TEC). This adjustment was made as a result of the recent Cost, Scope and Schedule Rebaselining review that took place in September 2001, as well as a staff review of the results of the Rebaselining review. The increase in the TEC/TPC has been approved by the Department of Energy.

There are several causes for the TEC change. Due to a tight market for civil construction, the cost for excavating tunnels and halls at the Fermi National Accelerator Laboratory (Fermilab) is considerably higher than the initial estimate. Rebidding this subcontract to reduce its cost entailed a significant delay, as has the subsequent performance of the work. Treatment and disposal of tunnel discharge water has also increased the cost. Experience has demonstrated that inadequate engineering resources were initially applied to the project. Thus, the cost of beam-line components was underestimated. The difficulty of constructing an underground facility to safely accommodate the extremely high intensity proton beam needed to produce an adequate number of neutrinos was also underestimated. The shielding required to suppress the secondary radioactivity has turned out to be significantly more extensive than originally planned, and the radiation levels near the target station will require a significant remote handling capability for routine operation and maintenance. The beam-line technical components costs now reflect results of a prototyping program along with more refined engineering estimates; labor is a substantial part of the increase. Also, the overall contingency on the TEC has been adjusted to reflect these changes. Both the Department of Energy and Fermilab have strengthened their management to execute the project within the new baseline.

The MINOS detector for NuMI, funded as part of the Other Project Costs, is proceeding well, and the contingency and the projected total cost for the detector have been reduced accordingly. Completion is expected within the revised project cost and schedule.

The funding schedule for the project now extends through FY 2005, with operation of the NuMI facility starting in FY 2005.

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 1998 Budget Request *(A-E and technical design only)*	1Q '98	4Q '98	NA	NA	5,500	6,300
FY 1999 Budget Request (Preliminary Estimate)	--	3Q '99	1Q '99	4Q '02	75,800	135,300
FY 2000 Budget Request	3Q '98	2Q '00	3Q '99	2Q '03	76,200	136,100
FY 2001 Budget Request	3Q '98	2Q '00	3Q '99	2Q '04	76,200	138,600
FY 2001 Budget Request (Amended)	3Q '98	2Q '00	3Q '99	4Q '03	76,200	138,400
FY 2002 Budget Request	3Q '98	4Q '00	3Q '99	4Q '03	76,149	139,390
FY 2003 Budget Request	3Q '98	4Q '00	3Q '99	4Q '05	109,242	171,442

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Design & Construction			
1998	5,500	5,500	1,140
1999	14,300	14,300	5,846
2000	22,000	22,000	15,089
2001	22,949	22,949	19,752
2002	11,400	11,400	30,000
2003	20,093	20,093	20,000
2004	12,500	12,500	14,000
2005	500	500	3,415

3. Project Description, Justification and Scope

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

The primary element of the project is a high flux beam of neutrinos in the energy range of 1 to 40 GeV. The technical components required to produce such a beam will be located on the southwest side of the

Fermilab site, tangent to the new Main Injector accelerator at the MI-60 extraction region. The beam components will be installed in a tunnel of approximately 1.5 km in length and 6.5 m diameter. The beam is aimed at two detectors (MINOS), which will be constructed in experimental halls located along the trajectory of the neutrino beam. One such detector will be located on the Fermilab site, while a second will be located in the Soudan Underground Laboratory. Two similar detectors in the same neutrino beam and separated by a large distance are an essential feature of the experimental plan.

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

4. Details of Cost Estimate [a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs	7,150	7,150
Design Management costs (0.0% of TEC)	10	10
Project Management costs (0.0% of TEC)	20	20
Total, Engineering design inspection and administration of construction costs (6.6% of TEC)	7,180	7,180
Construction Phase		
Buildings	12,228	8,320
Special Equipment	20,902	10,120
Other Structures	41,265	30,960
Construction Management (6.3% of TEC)	6,846	4,590
Project Management (4.4% of TEC)	4,788	2,170
Total, Construction Costs	86,029	56,160
Contingencies		
Design Phase (0.0% of TEC)	0	2,172
Construction Phase (14.7% of TEC)	16,033	10,637
Total, Contingencies (14.7% of TEC)	16,033	12,809
Total, Line Item Cost (TEC)	109,242	76,149

[a] The annual escalation rates assumed for FY 1999 through FY 2005 are 2.4, 2.8, 2.7, 3.0, 3.1, 3.4, and 3.3 percent respectively.

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.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Years	FY 2001	FY 2002	FY 2003	Outyears	Total
Project Cost						
Facility Cost						
Total, Line item TEC................................	22,075	19,752	30,000	20,000	17,415	109,242
Other Project Costs						
Capital equipment [a]................................	7,627	9,571	14,681	9,928	2,703	44,510
R&D necessary to complete construction [b]	1,300	0	0	0	0	1,300
Conceptual design cost [c]........................	830	0	0	0	0	830
Other project-related costs [d]	8,542	3,069	3,725	224	0	15,560
Total, Other Project Costs.............................	18,299	12,640	18,406	10,152	2,703	62,200
Total Project Cost (TPC)...............................	40,374	32,392	48,406	30,152	20,118	171,442

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

7. Related Annual Funding Requirements

(FY 2003 dollars in thousands)

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

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

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

Biological and Environmental Research

Program Mission

For over 50 years the Biological and Environmental Research (BER) program has been advancing environmental and biomedical knowledge that promotes national security through improved energy production, development, and use, international scientific leadership that underpins our nation's technological advances, and environmental research that improves the quality of life for all Americans. BER supports these vital national missions through competitive and peer-reviewed research at National Laboratories, universities, and private institutions. In addition, BER develops and delivers the knowledge needed to support the President's National Energy Plan, provides the science base in support of the Energy Policy Act of 1992, and works cooperatively with DOE's national security programs to develop tools to combat terrorism.

Strategic Objective

SC3: By 2010, develop the basis for biotechnology solutions for clean energy, carbon sequestration, environmental cleanup, and bioterrorism detection and defeat by characterizing the multiprotein complexes that carry out biology in cells and by determining how microbial communities work as a system; and determine the sensitivity of climate to different levels of greenhouse gases and aerosols in the atmosphere and the potential consequences of climate change associated with these levels by resolving or reducing key uncertainties in model predictions of both climate change that would result from each level and the associated consequences.

SC7: Provide major advanced scientific user facilities where scientific excellence is validated by external review; average operational downtime does not exceed 10% of schedule; construction and upgrades are within 10% of schedule and budget; and facility technology research and development programs meet their goals.

Progress toward accomplishing these Strategic Objectives will be measured by Program Strategic Performance Goals, Indicators and Annual Targets, as follows:

Program Strategic Performance Goals

SC3-1: Determine, compare, and analyze DNA sequences of microbes and other organisms that will underpin development of biotechnology solutions for clean energy, carbon sequestration, environmental cleanup, and bioterrorism detection and defeat. (Life Sciences, Environmental Remediation, and Medical Applications and Measurement Science subprograms)

Performance Indicator

Base pairs of DNA sequenced per year.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
By the end of FY 2001, the DOE Joint Genome Institute (JGI) completed the sequencing and submission to public databases of an additional 100 million finished and 250 million high quality draft base pairs of DNA, including both human and model organisms (e.g., the mouse) as part of the Human Genome Program. (SC2-1) [Exceeded goal]	By the end of FY 2002, the DOE Joint Genome Institute will complete the high quality DNA sequence of human chromosomes 16 and 19 and produce 6 billion base pairs of DNA sequence from model organisms (e.g., mouse, Fugu, and Ciona) to help understand the human sequence as part of the Human Genome Program. (SC3-1)	Complete the high quality DNA sequence of human chromosome 5. (SC3-1) Increase the DNA sequencing capacity of the DOE Joint Genome Institute (JGI), with no additional funding, to approximately 8 billion base pairs of DNA sequence per year, a 100% increase in the projected capacity over FY 2001. Establish at least 30 diverse collaborations for high throughput DNA sequencing with scientists outside the JGI important for Genomics and Genomes to Life research. (SC3-1)
Completed the genetic sequencing of three additional microbes that produce methane or hydrogen from carbonaceous sources and that could be used to sequester carbon as part of the Microbial Genomics and Carbon Sequestration programs. (SC2-1) [Exceeded goal]	Produce draft DNA sequence of more than 30 microbes that cover a range of functional relevance to DOE's life and environmental sciences and security missions - including carbon sequestration, environmental cleanup, bioremediation, and bioterrorism. (SC3-1)	Produce draft DNA sequences of more than 30 microbes vital to future U.S. energy security and independence, carbon sequestration, and environmental cleanup. (SC3-1)

SC3-2: Establish the scientific foundation for determining a safe level of greenhouse gases and aerosols in the atmosphere by resolving or reducing key uncertainties in predicting their effects on climate, and provide the foundation to predict, assess and mitigate potential adverse effects of energy production and use on the environment. (Climate Change Research subprogram)

Performance Indicator

Climate model resolution.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Conducted five Intensive Operations Periods (IOPs) on schedule at the Atmospheric Radiation Measurement (ARM) Southern Plains site in Oklahoma. Obtained data from second station on the North Slope of Alaska, and made operational the third station in the Tropical Western Pacific on Christmas Island on schedule and within budget in accordance with program plan. (SC2-1) [Met goal]	Develop and test a fully-coupled atmosphere-ocean-land-sea ice climate model that has twice the spatial resolution of coupled models available in 2000 as part of Climate Modeling and Prediction research. Support multi-disciplinary teams of scientists at multiple institutions using DOE supercomputers to perform model simulations, diagnostics, and testing. (SC3-2)	Improve the precision of climate models by delivering a more realistic cloud submodel that reduces the uncertainty in calculations of the atmospheric energy budget by 10 percent and by increasing the spatial resolution of the atmospheric and ocean and sea ice submodels to 1.4 degrees (about 150 Kilometers) and approximately 0.7 degrees (about 75 Kilometers), respectively, for the fully coupled climate model. (SC3-2)

SC7-3: Manage all BER facility operations and construction to the highest standards of overall performance, using merit evaluation with independent peer review. (Life Sciences, Environmental Remediation subprograms).

Performance Indicator

Percent on time/on budget, percent unscheduled downtime.

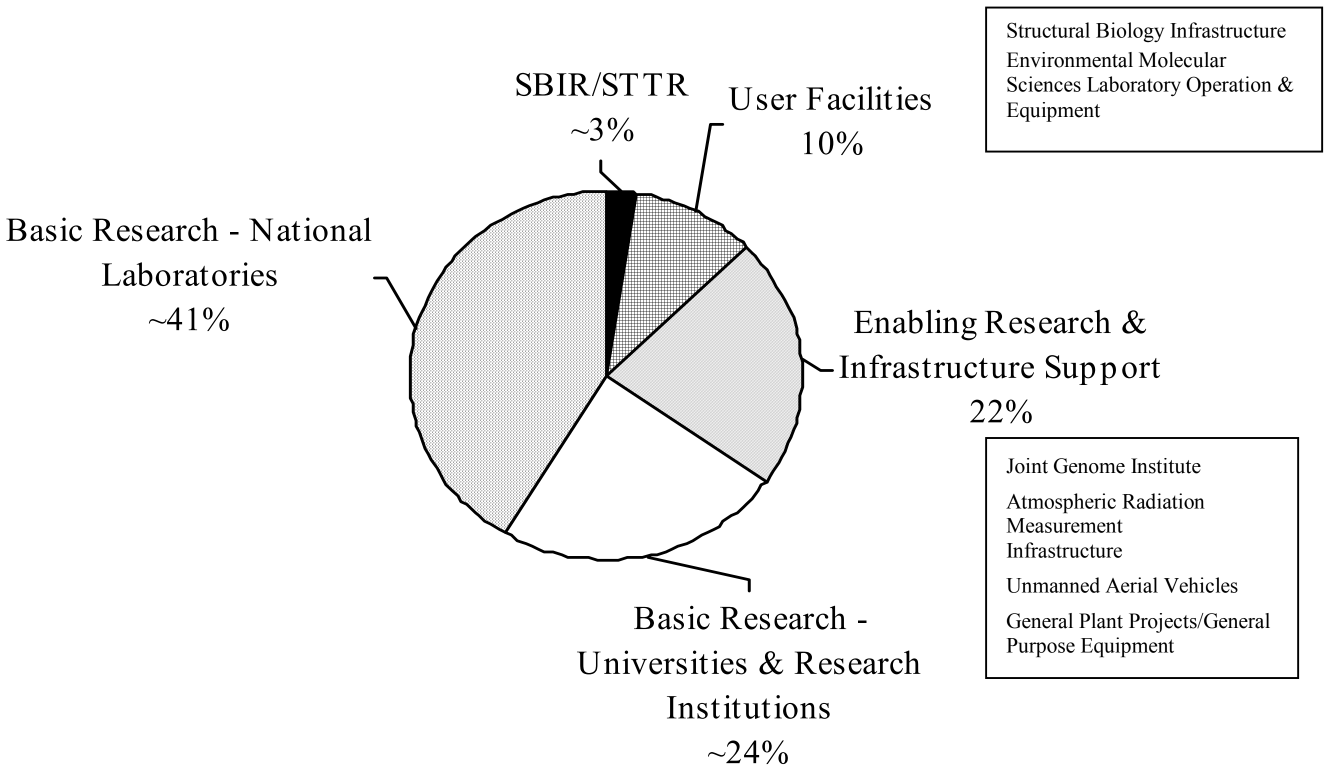
Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Keep within 10 percent of cost and schedule milestones for upgrades and construction of scientific user facilities, initiate commissioning of the protein crystallography Structural Biology User Station at the Los Alamos National Laboratory and initiate construction of the Center for Comparative and Functional Genomics at Oak Ridge National Laboratory. [Met Goal]	Keep within 10 percent of cost and schedule milestones for upgrades and construction of scientific user facilities; begin acceptance testing of the new high performance computer at the Environmental Molecular Sciences Laboratory at the Pacific Northwest National Laboratory; continue construction of the Center for Comparative and Functional Genomics at Oak Ridge National Laboratory. (SC7-3)	Keep within 10 percent of cost and schedule milestones for upgrades and construction of scientific user facilities; begin operation of the new high performance computer at the Environmental Molecular Sciences Laboratory at the Pacific Northwest National Laboratory; complete construction of the Center for Comparative and Functional Genomics at Oak Ridge National Laboratory. (SC7-3)
Maintain and operate the BER scientific user facilities so the unscheduled downtime on average is less than 10 percent of the total scheduled operating time. [Met Goal]	Maintain and operate the BER scientific user facilities so the unscheduled downtime on average is less than 10 percent of the total scheduled operating time. (SC7-3)	Maintain and operate the BER scientific user facilities so the unscheduled downtime on average is less than 10 percent of the total scheduled operating time. (SC7-3)

To accomplish the BER Program strategic goals, the BER budget request for FY 2003 is $504,215,000, including support for basic research, scientific user facility operations, and enabling research and infrastructure support. In addition, the program includes funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer program (STTR).



PROGRAM REVIEW, PEER REVIEW, AND USER FEEDBACK

Effective program review, peer review, and user feedback are critical tools for BER to measure performance of research programs, research projects, and user facilities. The quality and scientific relevance of the BER program and its individual research projects are maintained by rigorous peer reviews conducted by internationally recognized scientific experts. The criteria for determining scientific quality and relevance include scientific merit, appropriateness of the proposed approach and requested level of funding, and qualifications of the principal investigator. BER expects the highest quality research and, when necessary, takes corrective management actions based on results of the reviews. A measure of the quality of the BER research is the sustained achievement in advancing scientific knowledge. This is demonstrated by the publication of research results in the leading refereed scientific journals pertinent to BER-related research fields, by invited participation at national and international scientific conferences and workshops, and by honors received by BER-supported researchers. BER regularly compares its programs to the scientific priorities recommended by the Biological and Environmental Research Advisory Committee (BERAC), and by the standing committees created by the Office of Science and Technology Policy.

The BER program benefits from a diversity of program reviews. This is particularly the case for BER program elements that are components of international research endeavors, e.g., the International Human Genome Project and the U.S. Global Change Research Program. In addition to panel reviews used to evaluate and select individual projects and programmatic reviews by the chartered BERAC, BER evaluates its programs using interagency (and international) review bodies and by Boards and Committees of the National Academy of Sciences.

BER goes one step further in conducting program reviews. Panels of distinguished scientists are regularly 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 (WAG), involving physicists, mathematicians, engineers, etc., are among the organizations that study 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. The BER program is ideally positioned to facilitate and foster interactions between the physical sciences and the life sciences and aggressively pursues every opportunity to enhance the interface between the two scientific domains.

BER facility operations are also monitored by peer reviews and user feedback. BER manages these facilities 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. Facilities are also maintained and improved to remain at the cutting edge of technology and scientific capability.

The reviews and user feedback are incorporated as BER plans for the future needs of DOE research in the life and environmental sciences. This includes: planning for future directions, opportunities, and initiatives within the BER research portfolio; maintaining the flexibility to quickly move into promising new areas; contributing to the health of the educational pipeline in critical subfields and disciplines; planning for upgrades at existing facilities to expand the research capabilities or operational capacity; ensuring the proper balance between facilities and research; and planning for future facilities necessary to advance the science in areas relevant to BER's mission in close collaboration with the research community.

BER LEADERSHIP AND UNIQUE ROLES

The BER program fills a broad range of unique roles for the Department and the national and international scientific communities including:

- Manage research on microbes for energy, the environment, and national security and work with the Advanced Scientific Computing Research program to develop the computational methods and capabilities needed to advance understanding of complex biological systems, predict their behavior, and use that information to address DOE needs.
- Provide the facilities, instrumentation, and technology needed to (1) characterize the multiprotein complexes that result in microbial products and processes of use to DOE, and (2) determine the functional repertoire of complex microbial communities that can be used to address DOE needs.
- Develop cutting edge technologies, facilities, and resources, including animal models, for the Human Genome Project.

- Provide world leadership in low dose radiation research.
- Provide world-class structural biology user facilities and unique computational and experimental structural biology research emphasizing protein complexes involved in recognition and repair of DNA damage and remediation of metals and radionuclides.
- Provide world leadership in ground-based measurement of clouds and atmospheric properties to resolve key uncertainties in climate change, through the Atmospheric Radiation Measurement (ARM) program.
- Develop advanced predictive capabilities using coupled climate models on massively parallel computers for decade-to-century long simulations of climate change.
- Support fundamental research on carbon sequestration to develop technologies that enhance the uptake of carbon in terrestrial and ocean ecosystems.
- Provide world-class scientific user facilities for environmental and climate change research.
- Provide world leadership in radiopharmaceutical development for wide use in the medical and research communities.
- Maintain world leadership in detector development for medical and biological imaging.
- Enable interdisciplinary teams of scientists to use the unique resources in physics, chemistry, material sciences, and biology at the National Laboratories to develop novel medical applications.
- Manage the Environmental Management Science Program (EMSP) in consultation with the Office of Environmental Management (EM) to identify and select the appropriate fundamental research activities.
- Ensure that the rights and welfare of human research subjects at the Department are protected while advances in biomedical, environmental, nuclear, and other research lead to discoveries that benefit humanity.

Significant Accomplishments and Program Shifts

SCIENCE ACCOMPLISHMENTS

Life Sciences

- *Human DNA Sequence Published* - Capping what may be one of the greatest scientific achievements of all time, the draft human DNA sequence was published in the February 15/16, 2001 issues of the journals *Nature* and *Science.* DOE initiated this monumental research project, sequenced human chromosomes 5, 16, and 19, and contributed many of the fundamental technologies and resources. Both the human DNA sequence and high throughput DNA sequencing capabilities, especially as applied to microbes, contribute to the identification of genetic factors that increase individual human susceptibility to radiation and other energy-related materials and to the use of microbes and microbial communities to solve challenges in carbon sequestration, clean energy, environmental cleanup, and national security.
- *Understanding Human Chromosome 19 by Studying the Mouse* - Interpreting the recently completed human DNA sequence and understanding the role each gene plays in human development, health and susceptibility is one of the next major challenge in biology. Identifying all the components of each human gene is made easier by comparing the human DNA sequence with the comparable

sequence in the mouse, sequences that have been remarkably conserved by evolution. The JGI has sequenced more than 42 Megabases (Mb) of the mouse genome that codes for genes related to those found on human chromosome 19. For a particular gene-rich region of human chromosome 19, called HSA 19, research to date has shown that direct counterparts of virtually all known genes in the HSA 19 region are found in the mouse. In particular, these initial comparisons identified both new genes and candidate regulatory regions that had not been found with "gene-finding" software.

- *Sequencing the Pufferfish to Understand the Human Genome* - Scientists searching the human genome for genes and their on/off switches will soon have a valuable new resource courtesy of the Japanese delicacy known as Fugu, or the pufferfish. Evolution has conserved many of the DNA sequences that code for genes or their regulatory sequences. Comparisons of genome sequences between species are, therefore, an effective and efficient means of finding new genes and gene regulatory (controlling) elements. The Fugu genome, is 8-fold more compact than the human genome, making it even more cost-effective for these comparisons than yeast, fly, worm, and mouse. In FY 2001, DOE's Joint Genome Institute, together with its international partners, determined more than 90-percent of the Fugu genome sequence and made it available in an accessible database.
- *DOE Investments in Structural Biology Make Big Payoffs* - Understanding the three dimensional structure of proteins is an important step in understanding how the information contained in genes is put into action. This knowledge has important applications in medicine, clean energy production, carbon sequestration, and environmental cleanup since proteins make biology "happen" whether in people or microbes. DOE investments in structural biology research, at user facilities at synchrotron light sources, and in the technologies for speeding the determination of protein structure have enabled the National Institute of General Medical Sciences at the National Institutes of Health to make a large investment (over $25,000,000 in FY 2001) in pilot projects for the NIH's new Protein Structure Initiative to develop high throughput methods for determining protein structure. Five of the seven initial pilot projects include partners from DOE Laboratories and nearly all are using DOE user facilities.
- *Approaching High Throughput Proteomics* - Pacific Northwest National Laboratory has developed a "next generation" instrument for quantitative high throughput proteomic studies of microorganisms that also holds promise for studies of higher organisms including mouse and human. Initial studies with the highly radiation resistant microorganism *Deinococcus radiodurans,* now being extended to *Shewanella oniedensis,* (both important in bioremediation and waste cleanup), gave precise, proteome-wide measurements of changes in protein abundances based on the use of atomic mass tags and a stable-isotope labeling method, thus, allowing effective comparison of the proteome of an organism under two different experimental conditions.
- *Record Breaking Year of Microbial DNA Sequencing* - In FY 2001 the DOE Joint Genome Institute (JGI) sequenced over 20 different microbial genomes. The high draft sequence quality enabled 95% of the genes in these organisms to be identified. This is the largest microbial data set produced in such a small period of time, making the JGI one of the largest producers of microbial genomic sequence. The microbes cover a range of functional relevance to DOE's life and environmental sciences mission - from carbon sequestration to environmental, bioremediation, and medical relevance. Each microbe had a scientific "champion" to ensure rapid and public dissemination and use of the data. This draft sequencing effort is part of an ongoing scientific test to determine the most effective way to generate and disseminate the largest amount of useful DNA sequence information to the scientific community in the shortest, most cost effective manner.

- *White Rot Fungus Sequenced* - In FY 2001, the JGI completed the draft DNA sequence of the 30 Mb White rot fungus, *Phanerochaete chrysosporium*. This is one of the first fungal genomes to be sequenced and is a landmark in the use of whole genome shotgun strategies and the testing of the JGI's genome assembler software. The white rot fungus genome is very important to current research in the areas of biomass conversion, carbon sequestration, and cellulose and lignin digestion as well as PCB detoxification.
- *Resolving A-Bomb Dosimetry After More than 50 Years* – BER, working with DOE's Office of Environment, Safety and Health; National Research Council; and RERF (Radiation Effects Research Foundation) is resolving A-bomb dosimetry after more than 50 years. This effort was conducted in response to a directive from Congress to the BER program. Standards for protecting people from exposure to ionizing radiation are based, in large part, on analyses of the survivors of the atomic bombs in Hiroshima and Nagasaki. However, these analyses have large uncertainties due to uncertainties in the estimated doses of radiation received by the survivors. New technologies for measuring irradiated materials and greatly increased computational capabilities are now leading to the development of a new dosimetry system for A-bomb survivors that will be completed in early 2002. This new A-bomb dosimetry will be used for the development of future radiation protection standards, important both for future uses of nuclear energy and for ongoing clean up of contaminated DOE sites.

Climate Change Research

- *Improvements in Measurements and Modeling of Atmospheric Radiation Improves Weather Forecasts* - Through improvements in measurement techniques and related climate model radiation codes, the ARM program has improved the agreement between measured and modeled instantaneous clear sky infrared fluxes from 20 Watts/m^2 to 5 Watts/m^2. The inclusion of the advanced radiation code into climate models has resulted in a 7 percent improvement in the usefulness of weather forecasts by extending the forecast period and reducing the computation time required to produce the forecasts.
- *Consistency Documented Between Observed Temperature Changes in the Atmosphere and Ocean and Model Simulated Temperature Changes* - The Parallel Climate Model (PCM), a collaborative climate modeling effort supported by BER at the National Center for Atmospheric Research and Los Alamos National Laboratory, with contributions from several other DOE National Laboratories and academic institutions, was applied to the problem of identifying whether a greenhouse-gas climate signal exists in the observational climate record. BER-supported researchers at Scripps Institution of Oceanography compared two ensembles of PCM simulations of the last 300 years. The first ensemble was a series of simulations that included observed increases in greenhouse gas and sulfate aerosol concentrations resulting from anthropogenic activities. The second ensemble was a series of "control runs" identical to the first series, except that the increases of greenhouse gas and sulfate aerosol concentrations were excluded. The results show that the simulated regional temperature changes in both the atmosphere and the ocean were statistically consistent with the observed data, the first time that a model has demonstrated the ability to realistically simulate both the atmosphere and the ocean. The analysis further revealed a statistically significant pattern of temperature differences between the forced simulations and the control run ensemble that can be attributed to human-induced climate change.
- *Understanding of Complex Pollution Phenomena Advanced* - Data from the Texas Air Quality Study (TexAQS 2000) has provided new information on the relative importance of emissions from

refineries and other sources of ozone and aerosols and the recirculation of polluted air from land and sea breezes in causing violations in ozone and particulate air quality standards in the Houston area. The research was an interagency effort supported by DOE, EPA, NOAA, NSF, TVA, NASA, the Texas Natural Resources Conservation Commission, and the Greater Houston Partnership. Information from this study is being provided to Texas authorities developing air quality improvement plans. Advances in the science are also being incorporated in predictive and assessment models that can then be applied to other urban areas.

- *Assessment of "Background" Sources of Ozone in Urban Areas* - Research using numerical chemistry and atmospheric transport models has improved our understanding of the processes that govern tropospheric ozone, other oxidants, and aerosols on urban, regional, and global scales. A major question is whether horizontal transport by winds over regional distances, up to about 1000 kilometers, can substantially influence concentrations of these pollutants in U.S. metropolitan areas. Evaluation of data from recent field studies showed that ozone produced in southern California might be carried to the Phoenix area, thus altering the effectiveness of potential localized controls on energy-related emissions that contribute to oxidant formation where the current urban background concentration is about 40 parts per billion by volume (ppbv). Surface ozone concentrations can be elevated over this background by 5 to 25 ppbv, usually in episodic events by this regional scale transport. In addition, transport of ozone from the stratosphere can increase surface ozone by 10 ppbv or more near the surface.
- *AmeriFlux Network Increased to 40 Sites for Measuring N. American Terrestrial Carbon Sink* - The AmeriFlux network where net carbon dioxide (CO_2) exchange between the atmosphere and ecosystems across North America is measured, increased to 40 locations. The systematic net carbon dioxide exchange measurement offers one approach for estimating how much excess carbon dioxide from fossil fuel combustion is sequestered by terrestrial ecosystems. Over the past 3 years, annual net production or carbon gain of the instrumented forest sites ranged from 2 to 4 metric tons per hectare. For example, the carbon gain by deciduous forest ecosystems averages 6 grams of carbon per square meter per day. Net production generally increased with growing season length, which means that early onset of the growing season, or longer growing seasons associated with future climate changes can theoretically lead to more carbon sequestration. Related scientific research also determined that cloudiness leads to more efficient photosynthetic use of light by the plants to fix carbon. Web-based AmeriFlux data are disseminated to the scientific community by the Carbon Dioxide Information and Analysis Center where, in 2000, over 30,000 inquiries from 24 countries were recorded on the web site. In addition, the network is providing both high quality, real-time micrometeorological data for modeling ecosystem processes, and ground-truth plant productivity data for a NASA satellite platform designed to provide estimates of global ecosystem productivity.
- *Novel Ecological Results Obtained from Elevated-Carbon Dioxide Field Experiments* - Recent BER-sponsored Free-Air Carbon Dioxide Enrichment (FACE) field experiments that address DOE's mission to ensure that energy systems are environmentally sustainable have led to discoveries about ecosystem responses to future increases in atmospheric carbon dioxide levels resulting from fossil fuel combustion. In the southwestern U.S., a 50% increase in atmospheric carbon dioxide stimulated growth and seed production of an invasive annual grass species to a greater extent than native annual plants. This indicates that rising atmospheric carbon dioxide may favor exotic annual grasses, which might accelerate the fire cycle and reduce biodiversity in arid ecosystems. In a northern-U.S. FACE experiment, more diverse plant communities were found to respond more favorably to elevated carbon dioxide than less diverse communities, suggesting that biodiversity

losses could significantly affect how terrestrial ecosystems will respond to increasing atmospheric carbon dioxide. In a southeastern loblolly pine plantation in which 16 year old loblolly pines were exposed to elevated carbon dioxide, growth and carbon sequestration by this forest ecosystem were enhanced most when the poorest quality sites received both carbon dioxide and nutrient (nitrogen) amendments. The trees exposed to elevated carbon dioxide alone (55% above ambient) reached reproductive maturity at least two years sooner than trees exposed to the ambient carbon dioxide concentration. Elevated carbon dioxide also resulted in a disproportionate allocation of carbon to cones and seeds compared to tree stems (wood). The responses have implications for management of future forests regarding rotation intervals and selection of species grown for commercial purposes.

- *Fate of Injected Carbon Dioxide in the Deep Ocean Modeled* - LLNL researchers at the DOE Ocean Carbon Sequestration Consortium published a numerical simulation of the distribution of the relative carbon dioxide concentrations in the ocean resulting from a continuous 20-year injection of carbon dioxide at 1700 meters depth near Cape Hatteras, North Carolina. This simulated scenario showed that the injected carbon dioxide was transported under the Gulf Stream and remained isolated from the atmosphere for periods of decades or longer following the injection.
- *48 Students Enrolled in the Global Change Education Program for Undergraduate and Graduate Students* - Twenty-four outstanding undergraduate students were selected for participation in the 2001 DOE Summer Undergraduate Research Experience (SURE) and 24 exceptional graduate students were selected for DOE Graduate Research Environmental Fellowships (GREF), which provide support for their graduate research on climate change.

Environmental Remediation

- *Radiation Resistant Microbe Enzymatically Reduces Common Contaminants at DOE Sites* - The radiation resistant "superbug" *Deinococcus radiodurans* was shown by PNNL researchers to change chemical species of contaminants common to DOE sites (e.g., Uranium, Technetium, and Chromium) that are relatively soluble and mobile in water to unsoluble and relatively immobile species. Under conditions where ionizing radiation is high, such as sediments and soils beneath leaking waste storage tanks at some DOE sites, *Deinococcus radiodurans* may provide a means for limiting the migration of multivalent radionuclides and heavy metals. Moreover, *Deinococcus* has now been reported to be endemic to the populations of soil microorganisms beneath radioactive waste storage tanks at the Hanford reservation, making this microbe especially promising for *in situ* bioremediation approaches.
- *Portable Immunoassay Instrument Developed for Quantitative Measurement of Uranium in the Field* - A field portable immunoassay has been developed to measure uranium, a common legacy waste contaminant at DOE sites. Researchers at Tulane University developed an immunosensor that can be used for speciation and quantification of uranium in groundwater. A prototype hand held instrument has been developed in collaboration with Sapidyne Instruments. This technology makes it possible to rapidly obtain information on levels of uranium contamination and the effectiveness of remediation approaches for reducing or stabilizing uranium contamination at DOE sites.

Medical Applications and Measurement Science

- *PET/Radiotracer Studies Help Anti-addiction Drug Development* - The Brookhaven National Laboratory (BNL) uses positron emission tomography (PET) and radiotracer techniques to study the brain mechanisms underlying addiction. PET and carbon-11 studies with Vigabatrin also known as GVG, a drug used to treat epilepsy outside the U.S., have shown that GVG may prove to be an effective pharmaceutical treatment for cocaine addiction. In subsequent studies, Brookhaven scientists and collaborators found that the drug effectively blocked test animals' craving for nicotine, heroin, alcohol, and methamphetamine.
- *Tracking the Brain Dopamine Pathology Related to Obesity* - PET and carbon -11 radiotracer drug studies at BNL, recently published in *Lancet* 357, 354-357, 2001, provide evidence of brain dopamine pathology in obesity. The studies have shown that the brains of obese people have abnormalities in the chemical dopamine that regulates pleasure centers in the brain.
- *New Radiotracers to Study Stroke* - Lawrence Berkley National Laboratory scientists have developed a new radiotracer probe to study the brain biochemistry relevant to stroke. The tritiated compound, known as drug candidate CNS5161, will be used first as a research tool in animal models of stroke, trauma, drug addiction, and memory consolidation. The carbon-11 labeled form of this compound will be developed to assess acute brain biochemical receptor activation in human stroke and head trauma as well as for monitoring the more chronic changes in neurodegenerative disorders.
- *Helping the Blind See* - A collaborative research project at The Johns Hopkins Wilmar Eye Institute and at Oak Ridge National Laboratory (ORNL) in Tennessee is developing a retinal prosthetic device (an artificial retina) that will allow patients who have retinitis pigmentosa or age-related macular degeneration to see again. Significant progress has been made on the development of a micro-imaging sensor that is small enough that it can be safely implanted into the eye. Preliminary results predict that patients with retinitis pigmentosa or age-related macular degeneration will have vision restored to a level equivalent to reading large print.
- *New Biological Microscope Wins Discover Award* - A new microscope, that pairs optical confocal microscopy with magnetic resonance microscopy, has been developed by scientists at the Environmental Molecular Sciences Laboratory (EMSL). This new microscope, which combines the unique features of both technologies, will allow researchers to visualize in living cells, important morphological changes that occur when normal healthy cells transform into tumor cells.
- *Polymer Formulations for Cartilage Repair* - Pacific Northwest National Laboratory (PNNL) researchers have demonstrated that temperature sensitive polymers can support cartilage-forming cell growth outside the body and also provide a temporary synthetic “scaffold” to support growth of the newly grown cartilage cells once they are injected back into the joint.
- *Mini-Camera for Fewer Biopsies in Breast Cancer Diagnosis* - Researchers at Hampton University and the Thomas Jefferson National Accelerator Facility developed a gamma mini-camera that uses a specially modified personal computer for data acquisition and analysis. The smaller camera coupled to a superior imaging and high-performance processing system provides better resolution of the breast and is expected to result in fewer biopsies.
- *New Method for Cancer Risk Assessment* - Scientists at Ames Laboratory have developed a chip-based, direct-readout methodology for detecting and quantifying DNA adducts, chemical compounds in which a carcinogen is attached to the DNA. These chemical compounds can be present long before cancer develops and are critical in understanding early events in carcinogenesis.

- *New Radiopharmaceuticals for Cancer Therapy* - Investigators at Duke University have developed iodine-131 and astatine-211 labeled antitenascin-antibody proteins for treatment of brain tumors such as gliomas. The antibody proteins carrying the therapeutic doses of radiation can selectively seek tenascin molecules located on glioma cancer cells, bind and deliver the radiation for effective cancer cell killing.

FACILITY ACCOMPLISHMENTS

Life Sciences

- *New Neutron User Facility for Structural Biologists* - DOE user facilities for structural biologists at the synchrotron light sources enable scientists to determine high resolution electron density maps of protein crystals needed to determine their three dimensional structure. In some cases, neutrons provide additional information critical to understand protein structure by providing vital insights into the locations of hydrogen bonds and the nature of macromolecular-solvent interactions. A new protein crystallography station at the Los Alamos Neutron Science Center (LANSCE) will be available by the end of 2002. This is the only neutron crystallography station for structural biologists in the U.S.
- *New Ultrasensitive Mass Spectrometer for Proteomics* - Pacific Northwest National Laboratory has developed a new electrospray ionization fourier transform ion cyclotron resonance mass spectrometer (ICR), the highest field and most sensitive ICR mass spectrometer currently available. This new machine is approximately 1000 fold more sensitive than conventional instruments, has a resolution 100-1000 fold greater than conventional instruments and can measure peptides at a level less than or equal to 1 part per million. At this level, most peptides are unique and can be assigned to a specific protein in the genome. In contrast, conventional instruments measure at approximately the 500 parts per million level.

Environmental Remediation

- *Unique High Throughput Approach Using Mass Spectrometry for Proteome Characterization* - New mass spectrometry techniques developed by EMSL scientists are the basis for measuring changes in protein expression within a single experiment. This new approach can be used to monitor thousands to tens of thousands of proteins per day. The global perspective afforded by this new proteome measurement capability is diagnostic of changes within entire sets of cellular pathways and networks, thereby helps to identify those pathways key to a cell's state of development or response to a changing environment. The high throughput approach has been used to characterize the proteome of *Deinococcus radiodurans*, a microorganism with potential for bioremediating contaminated soils and groundwater. This approach confirmed almost half of the proteins predicted by genome annotation. Key to this successful project was the development of the ion funnel, a device that prevents ions in a sample from becoming lost by charge-charge repulsion of the ion beam as it is transferred into a mass spectrometer; greatly improved high pressure capillary liquid chromatographic separations; new methods for extending the dynamic range of measurements; and data processing methods that provide greater mass measurement accuracies for improved protein identification.

- *Computational and Experimental Chemistry Used to Determine New Estimate of Heat of Formation of OH Radical* - A team of scientists from EMSL and Argonne National Laboratory combined results from computational and experimental chemistry studies to determine a new value for the heat of formation of the hydroxyl radical (OH). This important result required use of the massively parallel supercomputer in EMSL and will have significant impact on models of combustion and atmospheric chemistry. The same approach has been used for many small, highly reactive species including those involved in fluorocarbon production and processing and the decomposition products of ammonia. Reliable prediction of the energetics of molecular systems is made possible by the revolution in computer hardware, software and computational methods and their application in computational chemistry.

PROGRAM SHIFTS

For FY 2003, BER will focus on:

- Further developing the research infrastructure needed for Genomes to Life research. The development of virtual, distributed research centers, begun in FY 2002, will expand to include research capabilities needed for analyses of the functional capabilities of microbial populations comprised of multiple microbial species, enabling the development of strategies to use complex microbial communities to address DOE needs in clean energy production, carbon sequestration, and environmental cleanup.
- With the completion of the high quality DNA sequence of human chromosomes 5, 16, and 19, DNA sequencing capabilities at the Joint Genome Institute will increasingly emphasize the needs of research on microbes for energy, the environment, and national security and, through interagency partnerships, selected sequencing needs of other agencies including the National Science Foundation and the U.S. Department of Agriculture.
- In FY 2003 the Administration will launch a new Climate Change Research Initiative (CCRI). The CCRI will focus on research areas where substantial progress in both understanding and prediction are likely over the next five years, including climate variation and change, carbon cycle, water cycle, atmospheric composition, and regional impacts. BER will participate in one of the specific areas: understanding the North American Carbon Cycle.
- Bioremediation research will continue its focus on the biotransformation of radionuclides and metals at contaminated DOE sites, the community of microbes that affect the transformations in subsurface environments at the sites, and the development of strategies for using bioremediation to clean up or stabilize these contaminants at DOE sites.
- In FY 2003 the Environmental Management Science Program and the Savannah River Ecology Laboratory are transferred from the Office of Environmental Management (EM) to the Office of Science. BER will manage these research activities according to Office of Science principles, but with extensive input from EM.
- In FY 2003, funding for the followup of all patients treated in the human clinical trials of boron neutron capture therapy (BNCT) at Brookhaven National Laboratory and the Massachusetts Institute of Technology will be completed with the transfer of clinical technology to the National Cancer Institute of the National Institutes of Health. The basic drug development research program for BNCT will evolve into a new program of innovative approaches to cell-targeted ablation therapy for cancer with in-vivo radiation techniques. The emphasis of this program will be on the

therapeutic use of ionizing radiation that may be achieved with radionuclide therapy and novel methods of tumor targeting.

Genomes to Life Research

The FY 2003 budget includes funds for the continued expansion of the research on microbes to address DOE's energy, environment, and national security mission needs. Initiated in FY 2002, this research will continue to more fully characterize the inventory of multiprotein molecular machines found in selected DOE-relevant microbes and higher organisms and to determine the functional diversity found in populations of microbes isolated from DOE-relevant sites. In FY 2003, new research will be initiated that focuses on further developing the research tools needed to study microbial communities that may have applications to clean energy, environmental cleanup, and carbon sequestration.

Climate Change Research Initiative

In FY 2003, the Administration will institute a new Climate Change Research Initiative (CCRI). The CCRI is intended to focus research on areas where substantial progress in understanding and prediction are likely over the next five years, including climate variation and change, carbon cycle, water cycle, atmospheric composition, and regional impacts. The set of cross agency programs will have strong focus on outcomes and deliverables. DOE, in conjunction with other USGCRP agencies, will begin a focused research program in specific research areas. The deliverables will be targeted at information useful to policy-makers (e.g., provide quantitative estimates of the carbon balance in regions across the U.S.). DOE will participate in one of the specific research areas: understanding the North American Carbon Cycle (with NOAA, NSF, and USDA).

Scientific Facilities Utilization

The Biological and Environmental Research request includes $52,088,000 to maintain support of the Department's major scientific user facilities. Facilities include structural biology research beam lines at the synchrotron light sources and the operation of the William R. Wiley Environmental Molecular Sciences Laboratory where research activities underpin long-term environmental remediation and other DOE missions in energy and national security. With this funding, BER will provide for the operation of the facilities, assuring access for scientists in universities, federal laboratories, and industry. BER will also leverage both federally and privately sponsored research.

Workforce Development

Workforce development is an integral and essential element of the BER mission to help ensure a science-trained workforce, including researchers, engineers, science educators, and technicians. The research programs and projects at the National Laboratories, universities, and research institutes actively integrate undergraduate and graduate students and post-doctoral investigators into the work. This "hands-on" approach is essential for the development of the next generation of scientists, engineers, and science educators. Specific fellowship programs are also sponsored by BER to target emerging areas of need. Over 1,500 graduate students and post-doctoral investigators will be supported at universities and at National Laboratories in FY 2002. BER will continue its support for graduate students and post-doctoral investigators in FY 2003. The number of graduate students and post-doctoral investigators will remain approximately at the FY 2002 level.

Graduate students and postdoctoral investigators use Office of Science user facilities. For example, they use the structural biology experimental stations on the beam lines at the synchrotron light sources and the instruments at the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL). Using these unique research tools enables the graduate students and post-doctoral investigators to participate in and conduct leading edge research. Approximately half of all of the facility users are graduate students and postdoctoral investigators. The graduate students and post doctoral investigators are supported by resources from a wide variety of sponsors, including BER, other Departmental research programs, other federal agencies, and U.S. and international private institutions. Graduate students and post-doctoral investigators at the synchrotron light sources are included in the Basic Energy Sciences (BES) user facility statistics and are not included here. A total of 500 graduate students and post-doctoral investigators conducted their research at the EMSL in FY 2001.

BER will continue its commitment to and dependence on research scientists at the Nation's universities. Approximately 40 percent of BER basic research funding directly supports university-based activities. University scientists are the major users at BER facilities and other enabling research infrastructure. University-based scientists are an integral part of research programs across the entire range of the BER portfolio. These scientists are funded through individual peer-reviewed grants and as members of peer-reviewed research teams involving both national laboratory and university scientists.

University-based scientists are the principal users of BER user facilities for structural biology at the synchrotron and neutron sources. They are also users of the Environmental Molecular Sciences Laboratory, and the Natural and Accelerated Bioremediation Research (NABIR) program's Field Research Center. University scientists also form the core of the Atmospheric Radiation Measurement (ARM) science team that networks with the broader academic community as well as with scientists at other agencies, such as the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration. In addition, university-based scientists are funded through Requests for Applications across the entire BER program including genomics, structural biology, low dose radiation research, global change research, bioremediation research, medical imaging, and radiopharmaceutical development. Furthermore, university scientists work in close partnership with scientists at National Laboratories in many BER programs including genomics, and carbon sequestration research.

Funding Profile

(dollars in thousands)

	FY 2001 Comparable Appropriation	FY 2002 Original Appropriation	FY 2002 Adjustments	FY 2002 Comparable Current Appropriation	FY 2003 Request
Biological and Environmental Research					
Life Sciences	188,469	193,385	-812	192,573	210,878
Climate Change Research	125,678	129,469	-547	128,922	137,959
Environmental Remediation	104,235	69,637	+44,764	114,401	109,530
Medical Applications and Measurement Science	93,187	123,509	-510	122,999	45,848
Subtotal, Biological and Environmental Research	511,569	516,000	+42,895	558,895	504,215
Construction	2,495	11,405	--	11,405	0
Subtotal, Biological and Environmental Research	514,064	527,405	+42,895	570,300	504,215
General Reduction	--	-2,155	2,155	0	--
Total, Biological and Environmental Research	514,064[a b c]	525,250	45,050	570,300[c]	504,215

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

[a] Excludes $11,088,000 which was transferred to the SBIR program and $665,000 which was transferred to the STTR program.

[b] Excludes $650,000 which was transferred to the Science Safeguards and Security program in an FY 2001 reprogramming.

[c] Includes $43,947,000 in FY 2001 and $45,050,000 in FY 2002 for Environmental Management Science Program and Savannah River Ecology Laboratory being transferred from Environmental Management.

Funding By Site

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	22,447	19,848	18,681	-1,167	-5.9%
Sandia National Laboratories	3,474	3,391	2,737	-654	-19.3%
Albuquerque Operations Office	1,597	900	850	-50	-5.6%
Total, Albuquerque Operations Office	27,518	24,139	22,268	-1,871	-7.8%
Chicago Operations Office					
Ames Laboratory	1,066	690	512	-178	-25.8%
Argonne National Laboratory – East	27,521	23,067	22,595	-472	-2.0%
Brookhaven National Laboratory	23,549	18,862	15,993	-2,869	-15.2%
Chicago Operations Office	92,092	47,702	46,146	-1,556	-3.3%
Total, Chicago Operations Office	144,228	90,321	85,246	-5,075	-5.6%
Idaho Operations Office					
Idaho National Engineering & Environmental Laboratory	1,440	1,056	400	-656	-62.1%
Idaho Operations Office	37,029	37,050	29,886	-7,164	-19.3%
Total, Idaho Operations Office	38,469	38,106	30,286	-7,820	-20.5%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	61,970	50,133	44,821	-5,312	-10.6%
Lawrence Livermore National Laboratory	33,450	32,715	36,899	+4,184	+12.8%
Stanford Linear Accelerator Center	3,656	4,170	5,550	+1,380	+33.1%
Oakland Operations Office	70,815	46,043	38,386	-7,657	-16.6%
Total, Oakland Operations Office	169,891	133,061	125,656	-7,405	-5.6%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science & Education	5,179	4,893	4,761	-132	-2.7%
Oak Ridge National Laboratory	45,798	45,134	33,085	-12,049	-26.7%
Oak Ridge Operations Office	380	352	352	0	--
Thomas Jefferson National Accelerator Facility	620	400	500	+100	+25.0%
Total, Oak Ridge Operations Office	51,977	50,779	38,698	-12,081	-23.8%

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Richland Operations Office					
Pacific Northwest National Laboratory	72,618	73,383	73,052	-331	-0.5%
Savannah River Operations Office	7,880	8,000	5,841	-2,159	-27.0%
Washington Headquarters	1,483	152,511	123,168	-29,343	-19.2%
Total, Biological and Environmental Research.........	514,064[a] [b] [c]	570,300 [c]	504,215	-66,085	-11.6%

[a] Excludes $11,088,000 which was transferred to the SBIR program and $665,000 which was transferred to the STTR program.

[b] Excludes $650,000 which was transferred to the Science Safeguards and Security program in an FY 2001 reprogramming.

[c] Includes $43,947,000 in FY 2001 and $45,050,000 in FY 2002 for Environmental Management Science Program and Savannah River Ecology Laboratory being transferred from Environmental Management.

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 the study of gene expression in real time and fluorescence spectroscopy to study environmental carcinogens.

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. At ANL, BER supports the operation of a high-throughput national user facility for protein crystallography at the Advanced Photon Source. In support of climate change research, ANL coordinates the operation and development of the Southern Great Plains, Tropical Western Pacific, and North Slope of Alaska ARM sites. 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 microbes. ANL, in conjunction with ORNL and PNNL and six universities, co-hosts the terrestrial carbon sequestration research center, CSiTE.

Brookhaven National Laboratory

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

The radiotracer chemistry, radiopharmaceutical technology, and magnetic resonance imaging research and development programs support applications of novel techniques for imaging brain function in normal and diseased states, and to study the biochemical basis of disease.

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

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. Using unique DOE capabilities such as advanced software for controlling neutron beams and calculating dose, 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 to tumors, including brain tumors. Research is also supported into the analytical chemistry of complex environmental and biological systems using the technique of mass spectrometry.

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 DNA sequencing techniques and studies on the biological functions associated with newly sequenced human DNA. A significant component of the JGI's sequencing goal is the development and integration of instrumentation, automation, biological resources, and data management and analysis tools into a state-of-the-art DNA sequencing assembly line that is highly efficient and cost effective. The laboratory also conducts research on the molecular mechanisms of cell responses to low doses of radiation and on the use of model organisms to understand and characterize the human genome.

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

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 geophysical and biophysical research capabilities for NABIR field sites. BER supports research at LBNL into new technologies for the detailed characterization of complex environmental contamination. LBNL also develops scalable implementation technologies that allow widely used climate models to run effectively and efficiently on massively parallel processing supercomputers. The carbon cycle field experiment at the ARM Southern Great Plains site is maintained and operated by LBNL.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on an 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 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 on the use of model organisms to understand and characterize the human genome.

Through the program for Climate Model Diagnostics and Intercomparison, LLNL provides the international leadership to understand and improve climate models. Virtually every climate modeling center in the world participates in this unique program.

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 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. One of LANL's roles in the JGI involves the production of high quality "finished" DNA sequence. LANL also conducts research on the molecular mechanisms of cell responses to low doses of radiation and on research 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 provides the site manager for 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 using massively parallel computers.

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

Oak Ridge Institute for Science and Education

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

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

Oak Ridge National Laboratory

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

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 uses mice as model organisms to understand and characterize the human genome.

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

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

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

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 scientists, including EMSL scientists, play important roles in both supporting the NABIR program and in performing research for NABIR.

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 engineering activity; this provides invaluable logistical, technical, and scientific expertise for the program.

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

PNNL conducts research on the molecular mechanisms of cell responses to low doses of radiation and on the development of high throughput approaches for characterizing all of the proteins (the proteome) being expressed by cells under specific environmental conditions.

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

PNNL also conducts research on the integrated assessment of global climate change.

In March 2001 the University of Maryland and Pacific Northwest National Laboratory created a Joint Global Change Research Institute in College Park, Maryland. The Institute investigates the scientific, social, and economic implications of climate change, both nationally and globally. BER funding supports research grants to the university and research projects to PNNL that have been successfully peer reviewed in open competition.

Sandia National Laboratory

Sandia National Laboratory (SNL) is a Multiprogram Laboratory, with a total of 3,700 acres, located in Albuquerque, New Mexico, with sites in Livermore, California and Tonopah, Nevada. SNL provides the site manager for 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. The laboratory conducts advanced research and technology development in robotics, smart medical instruments, microelectronic fabrication, and computational modeling of biological systems.

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

Savannah River Site

The Savannah River Site complex covers 198,344 acres, or 310 square miles encompassing parts of Aiken, Barnwell and Allendale counties in South Carolina bordering the Savannah River. At the Savannah River Site, BER supports the Savannah River Ecology Laboratory (SREL), a research unit of the University of Georgia operating at the site for over forty years. The SREL conducts research aimed at reducing the cost of environmental cleanup and remediation while ensuring biodiversity to the restored environment.

BER supports the Savannah River Ecology Laboratory through a cooperative agreement with the University of Georgia. The ecological research activity is aimed at reducing the cost of cleanup and remediation while ensuring biodiversity to the restored environment.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center (SLAC) is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California, and is the home of the Stanford Synchrotron Radiation Laboratory (SSRL). The Stanford Synchrotron Radiation Laboratory was built in 1974 to utilize the intense x-ray beams from the SPEAR storage ring that was built for particle physics by the SLAC laboratory. Over the years, the SSRL grew to be one of the main innovators in the production and use of synchrotron radiation with the development of wigglers and undulators that form the basis of all third generation synchrotron sources. The facility is now comprised of 25 experimental stations and is used each year by over 700 researchers from industry, government laboratories and universities. Through the Stanford Linear Accelerator Center, BER (in coordination with the National Institutes of Health) is funding the operation of nine 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.

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. BER supports the development of advanced imaging instrumentation at TJNAF that will ultimately be used in the next generation medical imaging systems.

All Other Sites

The BER program funds research at nearly 340 institutions, including colleges/universities, private industry, and other federal and private research institutions located in 43 states. Also included are funds for research awaiting distribution pending completion of peer review procedures.

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

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

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

Peer-reviewed projects are supported in each element of the Climate Change Research 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.

In the NABIR program, 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 the nuclear medicine program, universities conduct research into new types of radiopharmaceuticals, particularly those based on application of concepts from genomics and structural biology. BER places emphasis on radiopharmaceuticals that will be of use in advanced imaging techniques such as positron emission tomography. The research supports new instrumentation for medical imaging. The BER Measurement Science program supports research into novel types of biosensors for medical imaging and application in analytical chemistry of contaminated environments.

Life Sciences

Mission Supporting Goals and Objectives

The goal of the Life Sciences subprogram is to deliver knowledge in structural biology, genomics, and the health effects of low dose radiation. Human, animal, and microbial DNA sequencing will be used to understand the genetic and environmental basis of normal and abnormal function. Scientific tools will be developed to understand gene function and protein structure needed for biotechnology solutions for clean energy, carbon sequestration, environmental cleanup, and bioterrorism detection and defeat. Low dose radiation research will provide knowledge for rigorous, cost-effective standards to protect the health of cleanup workers and the public and for science-based decisions on DOE site cleanup operations.

BER's Life Sciences research is focused on developing, making available, and using unique DOE resources and facilities to understand and mitigate potential health effects of energy development, energy use, and waste cleanup, and develop novel biotechnology solutions for energy, environmental, and national security applications. BER supports research in five areas: structural and computational biology, low dose radiation, microbial biology, human genome, and biological research.

- BER develops and supports user facilities for the Nation's structural biologists; combines computer science, structural biology, and genome research for analyses and predictions of gene function from the individual gene to the genomic level; and develops new technologies and methodologies to understand the dynamic processes of protein-protein interactions that are unique to living organisms.
- BER supports research on low dose and low dose-rate radiation and addresses both the scientific issues and results with scientists, regulators, and the public to provide a better scientific basis for achieving acceptable levels of human health protection from low levels of ionizing radiation.
- BER takes advantage of the remarkable diversity of microbes found in the environment and our ability to identify and to understand how biological functions follow from the DNA sequence to the behavior of an entire organism. This information can help in the development of unique solutions in energy production, waste cleanup, and carbon management.
- BER is an integral part of the International Human Genome Project that has made publicly available a highly accurate sequence of the human DNA sequence. The BER Human Genome program also develops resources, tools, and technologies needed to analyze and interpret DNA sequence data from entire organisms, determines the function of the genes identified from DNA sequencing, and studies the ethical, legal, and social implications (ELSI) of information and data resulting from the genome project.
- Finally, BER's research program is developing the capability to predict how single cells and multi-cellular organisms respond to biological and environmental cues and to use this predictive capability to address DOE needs in energy, the environment, and for national security. This challenge starts with the remarkable progress being made in all other parts of the Life Sciences subprogram, from DNA sequencing to structural biology, and requires the development of new technologies, analytical methods, and modeling capabilities.

The Life Sciences subprogram's support of microbial genome research also contributes to the BER clean energy and carbon sequestration research programs. Knowing the genomic sequence of microbes that are involved in carbon sequestration or that produce methane and hydrogen, is enabling the identification of the key genetic and protein components of the organisms that regulate these processes. Understanding more fully how the enzymes and organisms operate will enable scientists to evaluate their potential use to remove excess carbon dioxide from the atmosphere or 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, produce hydrogen, and sequester the carbon dioxide by-product.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Structural Biology	35,975	27,927	27,847	-80	-0.3%
Molecular and Cellular Biology	49,387	58,272	73,264	+14,992	+25.7%
Human Genome	85,491	87,858	90,185	+2,327	+2.6%
Health Effects	17,616	13,640	14,251	+611	+4.5%
SBIR/STTR	0	4,876	5,331	+455	+9.3%
Total, Life Sciences	188,469	192,573	210,878	+18,305	+9.5%

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
Structural Biology	**35,975**	**27,927**	**27,847**
▪ **Basic Research**	**12,012**	**12,627**	**12,547**

BER will continue to invest in structural biology research. In biology, most proteins do not act independently in living systems. In carrying out their functions within cells, proteins form complexes with other proteins (molecular machines) and interact with a variety of structural and regulatory molecules on which proteins carry out their functions. The role of structure in determining protein interactions with diverse molecules in a cell is still poorly understood. Understanding how molecular machines carry out their biological functions requires that we observe dynamic changes in protein structure and study protein modifications, translocation, and subcellular concentrations.

Starting with DNA sequencing information, research is supported to predict or identify the proteins that are involved in the recognition or repair of radiation-induced DNA damage or in the bioremediation of metals and radionuclides that could lead to reduced clean up costs; and to determine the high-resolution three-dimensional structures of those proteins. To fully understand the mechanisms underlying the behavior of the molecular machines that carry out these functions, research is conducted and computer simulation models are developed: (1) on the dynamic changes in protein structure associated with protein modification and with protein-protein and protein-nucleic acid interactions that occur in these molecular machines; (2) to develop instrumentation that enables imagery of molecular machines in real-time at high levels of resolution; and (3) to precisely measure their intracellular compartmentalization and translocations.

DOE investment in structural biology research is having a large impact on basic research investments being made by other agencies. DOE investments in structural biology user facilities at synchrotron light sources and at the Environmental Molecular Sciences Laboratory (EMSL) and in development of key technologies for speeding the determination of protein structure have enabled the National Institute of General Medical Sciences at the National Institutes of Health (NIH) to make a large investment (over $25,000,000 per year from FY 2001 to FY 2005) in pilot projects for NIH's Protein Structure Initiative to develop high throughput methods for determining protein structure. Six of the seven initial pilot projects, funded by NIH, include partners from DOE Laboratories and nearly all are centered around DOE user facilities.

Performance will be measured by the development of experimental and computational models that can successfully predict which proteins interact with protein complexes involved in DNA damage recognition and repair or bioremediation of metals and radionuclides from analysis of DNA sequence.

	FY 2001	FY 2002	FY 2003
▪ **Infrastructure Development**	**23,963**	**15,300**	**15,300**

BER supports and develops beamlines and instrumentation for the Nation's structural biologists. It coordinates with the NIH and the NSF development and operation of experimental stations at DOE synchrotrons (Advanced Photon Source, Advanced Light Source, Stanford Synchrotron Radiation Laboratory and National Synchrotron Light Source) and neutron beam sources (the Los Alamos Neutron Science Center (LANSCE) and High Flux Isotope Reactor at ORNL). BER also supports access to mass spectrometry and nuclear magnetic resonance spectrometry user facilities at the EMSL that are used for both proteomic and structural biology research. University scientists are the principal users of these facilities.

Performance will be measured by having more than 2,500 highly satisfied users of the structural biology instruments at the DOE national user facilities.

By the end of FY 2003, BER's new (funded in FY 2001) DNA Repair Protein Complex Beamline at the Advanced Light Source at Lawrence Berkeley National Laboratory will be operational and available for users. This beamline will have novel features that include the ability to conduct both high-resolution (2 Angstrom) and low-resolution (2000 Angstrom) studies on important biomolecules using the same beamline. It will meet a rapidly growing need in the structural biology user community to provide unique information on functionally important conformational changes of multiprotein complexes and on factors that regulate the assembly of those complexes.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

BER also operates the neutron protein crystallography station at the Los Alamos Neutron Science Center (LANSCE) and will complete a new station for small angle neutron scattering at the High Flux Isotope Reactor (HFIR) at ORNL.

Performance will be measured by having ten external user groups use the LANSCE protein crystallography station and by beginning the commissioning of the Biological Small Angle Neutron Scattering Station at the Oak Ridge National Laboratory High Flux Isotope Reactor by the end of FY 2003.

BER also supports, with NSF and NIH, the Protein Data Bank for three-dimensional protein structures, a resource of growing importance that serves the NIH's high throughput structural genomics initiative as well as the Nation's life sciences research programs.

Unique facilities being developed at BER's Environmental Molecular Sciences Laboratory (EMSL) are now being made available to the structural biology user community.

Performance will be measured by the number of users resulting from the use of advanced mass spectrometry and nuclear magnetic resonance instrumentation at the Environmental Molecular Sciences Laboratory (EMSL) for structural biology and proteomics research.

Molecular and Cellular Biology	**49,387**	**58,272**	**73,264**
▪ **Microbial Genomics**	**13,345**	**10,868**	**10,928**

- *Microbial genomics research addresses DOE mission needs* – The program continues to sequence microbes that will be used to impact several DOE missions including: microbes for energy production (methane or hydrogen producing microbes), as alternative fuel sources (methane production or energy from biomass), for carbon sequestration, for helping to clean up the environment, and that are related to potential biothreat agents. The underlying scientific justification remains a central principle of the BER genome programs – complete genomic sequences yield answers to fundamental questions in biology. Knowing the complete DNA sequence of a microbe provides important keys to the biological capabilities of that organism and is the first step in developing strategies to more efficiently detect, counteract, use, or reengineer that microbe to address DOE needs.
- *Scientific needs of the DOE microbial genome program* – Now that the DNA sequence of more than 50 microbes with potential uses in energy, waste cleanup, and carbon sequestration have been determined, the program is beginning to further interpret and use that DNA sequence information. In FY 2003, the microbial genome program will continue to focus on 5 scientific challenges:
  - *Functional analysis* - It is presently difficult to predict biological function of novel genes from genomic sequence data. The program is developing better experimental and computational methods to identify these novel genes and predict the functions of the proteins they encode.

(dollars in thousands)

FY 2001	FY 2002	FY 2003

- *Bioinformatics* – More than a third of the nearly 100 publicly available genomic sequences of archaea and bacteria are a result of DOE Microbial Genome program funding. Novel computational tools are being developed to increase the value of microbial genomic information, such as identifying distant relationships of genes, understanding microbial evolution, predicting gene function, identifying and modeling gene expression networks, and extracting longer stretches of useable DNA sequence from raw sequence data.
- *Microbial Genomic Plasticity* – Current microbial DNA sequence data strongly suggests that entire blocks of genes have been transferred between microbes during evolution. Research is being conducted to assess the frequency, mechanisms, and circumstances of lateral gene exchanges among microbes. This understanding is important for interpreting sequence data and for designing novel strategies for using microbes to address DOE mission needs.
- *Novel Approaches to Microbial Genomic Sequencing* - Research is being conducted on new methods to accelerate sequence comparisons without resequencing the entire genome of the related organism from scratch. Emphasis is being placed on novel uses of proven technologies with a particular emphasis on the identification of specific DNA sequence features that are associated with phenotypic differences between the microbes being compared.
- *Consortia and Hard-to-Culture Microbes* **–** Most microbes in the environment neither live in isolation from other microbes or can be readily grown in the laboratory. Research is focused on the organization, membership, or functioning of consortia of microbes, especially those involved in environmental processes of interest to DOE or that use potential biothreat agents, and on the development of technologies that enable genomic analyses of these consortia without the need for isolating individual microbes.

Performance will be measured by drafting genomic sequence of more than 30 microorganisms of high DOE relevance and scientific research; improving the computational tools for predicting gene function; and by the development of methods for sequencing unculturable microbes and microbial consortia.

▪ **Carbon Sequestration Research**	**7,127**	**7,107**	**7,138**

Microbes play a substantial role in the global cycling of carbon through the environment. The main emphasis of the program in FY 2003 is to leverage this new genomic DNA sequence information to characterize key biochemical pathways or genetic regulatory networks in these microbes. Analysis of biochemical pathways has previously focused on single genes or small numbers of genes at one time. Research in this program will focus, as described above, on the development and use of new, high-throughput technologies to determine the function of new genes discovered from microbial DNA sequencing. The information on the DNA sequence, key reaction pathways, and genetic regulatory networks will be used to develop strategies to use microbes and other organisms capable of carbon sequestration more efficiently or to even reengineer these organisms to enhance their capacity to sequester excess atmospheric carbon.

	(dollars in thousands)	
FY 2001	FY 2002	FY 2003

Performance will be measured by the completion of a draft 3x DNA sequence of a member of the genus *Populus* (trees like poplar, aspen, etc.). These rapidly growing trees not only offer an opportunity for carbon sequestration, but also for bioremediation and energy from biomass. In addition, *Thalassiosira*, a diatom important in oceanic sequestration will also be draft sequenced.

- **Genomes to Life** **9,361** **21,514** **36,675**

  Research on microbes that address DOE energy, environmental, and national security needs continues to expand in FY 2003 as a research program on the leading edge of biology. The research will offer new biotechnology solutions to challenges related to DOE's missions in, for example, new clean energy sources, climate stabilization through carbon sequestration, toxic waste cleanup, and biothreat reduction.

  Microbes and plants are responsible for the initial production of essentially all carbon-based energy that we use, whether from oil, coal or biomass, and for the subsequent removal of the energy-related carbon from the atmosphere. Microbes and microbial communities also make up about 60% of the biomass on Earth and have the potential to make a substantial impact on energy production, sequestration of carbon from the atmosphere, and the cleanup of hazardous waste. A deeper, genetically based understanding of these organisms, culminating in computational models of their function that can be used to predict and even modify their functions or efficiencies, promises a revolution in energy production, use, and environmental impact. This research program is part of an interagency program to understand life's basic processes to meet National goals in many areas including health, agriculture, and energy.

  The availability of complete genome sequences for all manner of life on Earth has opened a new era and new opportunities in biology. Research on the biological processes involved in the carbon cycle will lead to new biological strategies for storing and monitoring carbon. Understanding metabolic pathways and their regulatory networks will allow us to more effectively use or create designer microbes or plants that produce and convert biomass for fuel, power, and products. Harnessing metabolic or regulatory pathways in hydrogen-producing microbes could provide an alternative and ultimately clean energy source. This new understanding will also enable development of better detection and prevention strategies for potential biothreat agents.

  We are just beginning to appreciate the potential applications of microorganisms. For all intents and purposes, ours is a microbial world filled with microscopic creatures that we take for granted and almost never even know are there. Microorganisms are Earth's recyclers, participating in the recycling of most biological materials on Earth. In the process they produce and, together with plants, take up greenhouse gases. Microbes in particular have evolved on Earth for some 3.8 billion years and, as suggested by their diversity and range of adaptation, have long ago solved many problems for which DOE is seeking solutions. It has been estimated that more than 99% of Earth's genetic and metabolic diversity, and, importantly, Earth's useable potential, reside in the microbial universe of bacteria, fungi, archaea, and minute protozoa and micro algae that collectively comprise the planktonic communities in the oceans and the majority of life in soil.

(dollars in thousands)

FY 2001	FY 2002	FY 2003

Underlying all potential applications of biotechnology to clean energy, mitigation of greenhouse gas effects on climate change, and environmental cleanup is the need for a solid understanding of the biochemistry and genetics of plants and microorganisms. We are only now beginning to appreciate the complexity of metabolic and regulatory signaling pathways in the simplest of bacteria that might be harnessed for clean energy and carbon management. Two simple examples: If, in the long-term, we are to enhance the productivity of forests, biomass crops and agricultural systems, it is imperative to understand why, for example, Rubisco--a mediator of photosynthesis and the single most abundant enzyme complex on Earth--is seemingly so energetically inefficient. This research program may show us that Rubisco can be engineered to carry out carbon fixation more efficiently, if its genetic regulatory circuits can be "rewired" or, perhaps, that there are more efficient forms of this enzyme still waiting to be discovered and used. Similarly, it may help to develop a more efficient hydrogen-based energy economy through an understanding of how oxygen poisons a key group of enzymes, hydrogenases, capable of producing hydrogen in the absence of air. This program will help us answer these types of questions.

The capture and sequestration of huge, gigaton volumes of carbon dioxide (CO_2) on a global scale from power generation and heavy industry is central to the success of any future strategy to control atmospheric greenhouse gases. This research program contributes to this challenge through its systems approach to understand biological systems at both the molecular and environmental (microbial community) levels that can point to possible applications of this new knowledge. With an appropriate geologic energy source, subsurface microbial communities under thermodynamically favorable conditions might be manipulated to convert sequestered CO_2 into biomass, and ultimately extractable methane. This program will also seek to understand the need to understand microbiological and biogeochemical mechanisms important to long-term geologic storage and leakage of stored CO_2.

Bioprocesses are often more energy efficient than current industrial processes. A key challenge, therefore, is to take advantage of and apply nature's efficiency to large-scale processing, a result that would help transform the energy economy. Bioconversion uses microorganisms such as bacteria and fungi or cell-free enzyme systems to capture energy or to transform organic or inorganic materials to useful products including fuel, food, fiber, and commodity and special chemicals. Heading the list of possibilities is the direct biological production of hydrogen and, perhaps in a simultaneous process, reducing the carbon density of coal, oil, and gas. Bioconversion also promises innovative approaches to clean energy and for mitigating greenhouse gas emissions by directly capturing emissions from industry and power generation. This program will provide the necessary knowledge base and the biotechnology tools to explore these possibilities.

Proteins rarely work alone. They assemble in larger multi-protein complexes often referred to as molecular machines. Understanding these molecular machines is a major goal of the research. Similarly, microbes of potential importance for DOE's energy and cleanup missions rarely work alone in nature. Microbes are often found as part of complex, and poorly understood consortia of many different types of microbes.

The research will:

- Identify life's molecular machines, the multiprotein complexes that carry out the functions of living systems. Emphasis will focus on molecular machines from organisms of potential importance to DOE missions (e.g., energy production, environmental remediation, and carbon sequestration, and biothreat reduction).
- Characterize the gene regulatory networks and processes that control the molecular machines of interest.
- Characterize the functional repertoire of complex microbial communities in their natural environments and use the integrated genomics, biochemical, structural, and physiological information to address DOE missions in energy, waste cleanup, and biothreat reduction.
- Develop computational capabilities needed to model the complexity of biological systems.

The overriding goal of this long-term research program is to understand biology well enough to be able to predict the behavior and responses of biological systems – from cells to organisms so that they can best be used to address DOE mission needs in energy, the environment, and national security.

Computation and modeling of biological processes and systems is key to the success of this effort given the complexity of biological systems. Greatly improved computational strategies, tools and resources are needed and will be developed in partnership with the Advanced Scientific Computing Research program. One goal is to bring terascale computing into Genomes to Life as a model for all biologists.

The broad goals of this research are shared with other agencies, such as the National Institutes of Health and the National Science Foundation, and private sector companies and will require coordination exceeding that of the Human Genome Project. The program will focus on scientific challenges that can be uniquely addressed by DOE and its National Laboratories in partnership with scientists at universities and will focus on high throughput genomic-scale activities (e.g., DNA sequencing, complex computational analysis, and genomic protein-expression experimentation and analysis) that are out of reach of individual investigators or even small teams.

The increase in funding will accelerate development of the research infrastructure needed to conduct the complex, multidisciplinary research. Funds will be used to develop peer-reviewed, virtual, distributed research centers comprised of teams of National Laboratory, university, and private sector scientists who, together will develop, use, and distribute research resources for the program.

Performance will be measured by:

- The funding of new, large multidisciplinary research teams comprised of scientists from National Laboratories and universities and by the successful partnering with research programs in other federal agencies.
- In conjunction with ASCR, develop new computational tools for the analysis and simulation of biological processes.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

- For 3-5 of the over 70 microbial genomes sequenced by DOE, begin the difficult, comprehensive integration of genomic, biochemical, structural and physiological information on DOE relevant functionalities (e.g., bioremediation, carbon sequestration and/or biomass to fuel). Develop working conceptual and numerical models to describe these functionalities.
- Sequence one or more consortia of microorganisms that will provide information on how microbes function and interact in the environment, such as at DOE legacy waste sites.

	FY 2001	FY 2002	FY 2003
▪ **Human Frontiers Science**	**1,000**	**1,000**	**1,000**

BER will continue to fund the Human Frontiers Science program, an international program of collaborative research to understand brain function and biological function at the molecular level supported by the U.S. government through the DOE, the National Institutes of Health, the National Science Foundation, and the National Aeronautics and Space Administration. This program continues to get high marks from the international scientific community about the quality of the science it supports, the multidisciplinary and collaborative nature of the research and its productivity. In FY 2002, DOE expects to explore the possibility of other agencies with stronger interests in brain function continuing the program allowing DOE to refocus its efforts on more mission relevant science. FY 2003 funding will complete DOE activities.

	FY 2001	FY 2002	FY 2003
▪ **Low Dose Radiation Research**	**18,362**	**17,783**	**17,523**

The goal of the Low Dose Radiation Research program is to support research that will help determine health risks from exposures to low levels of ionizing radiation, information that is critical to adequately, and appropriately, protect people and to make the most effective use of our national resources.

In FY 2003, BER will continue to emphasize the use of new tools such as microbeam irradiators developed in the program in prior years, the characterization of individual susceptibility to radiation, and the forging of closer, more productive linkages between experimentalists and risk modelers, a relationship that lies at the critical interface between experimental science, risk analysis, and development of better risk management policies. In particular, research will focus on:

- *Bystander effect* – the response of cells that are not directly traversed by radiation but respond with gene induction and/or production of potential genetic and carcinogenic changes. It is important to know if bystander effects can be induced by exposure to low LET (linear energy transfer) radiation delivered at low total doses or dose-rates. This bystander effect potentially "amplifies" the biological effects (and the effective radiation dose) of a low dose exposure by effectively increasing the number of cells that experience adverse effects to a number greater than the number of cells directly exposed to radiation.
- *Genomic instability* – is the loss of genetic stability, a key event in the development of cancer, induced by radiation and expressed as genetic damage that occurs many cell divisions after the insult is administered. Current evidence suggests that DNA repair and processing of radiation damage can lead to instability in the progeny of irradiated cells and that susceptibility to

instability is under genetic control but there is virtually no information on the underlying mechanisms. Its role in radiation-induced cancer remains to be determined experimentally. It is also important to determine if genomic instability occurs at low total doses (<10 rads) or low dose rates.

- *Adaptive response* – is the ability of a low dose of radiation to induce cellular changes that reduce the level of subsequent radiation-induced or spontaneous damage. If low doses of radiation regularly and predictably induce a protective response in cells to subsequent low doses of radiation or to spontaneous damage, this could have a substantial impact on estimates of adverse health risk from low dose radiation. The generality and the extent of this apparent adaptive response needs to be quantified.
- *Endogenous versus low dose radiation induced damage* - A key element of the program will continue to investigate the similarities and differences between endogenous oxidative damage and damage induced by low levels of ionizing radiation as well as an understanding of the health risks from both. This information was not previously attainable because critical resources and technologies were not available. Today, technologies and resources such as those developed as part of the human genome program and at the National Laboratories have the potential to detect and characterize small differences in damage induced by normal oxidative processes and low doses of radiation.
- *Genetic factors that affect individual susceptibility to low dose radiation* – Research is also focused on determining whether genetic differences make some individuals more sensitive to radiation-induced damage since these differences could result in individuals or sub-populations that are at increased risk for radiation-induced cancer.
- *Mechanistic and risk models* – Novel research is supported that involves innovative collaborations between experimentalists and modelers to model the mechanisms of key radiation-induced biological responses and to describe or identify strategies for developing biologically-based risk models that incorporate information on mechanisms of radiation-induced biological responses.

Information developed in this program will provide a better scientific basis for making decisions with regard to remediating contaminated DOE sites and for determining acceptable levels of human health protection, both for cleanup workers and the public, in a more cost-effective manner. University scientists, competing for funds in response to requests for applications, conduct a substantial fraction of the research in this program.

Performance will be measured: By the end of FY 2003, results from the Low Dose Radiation Research program will be incorporated into the National Academy of Sciences Biological Effects of Ionizing Radiation (BEIR) VII report that will serve as a basis for future policy decisions on low dose radiation.

		(dollars in thousands)	
	FY 2001	FY 2002	FY 2003
▪ **Congressional Direction**..	**192**	**0**	**0**

Congressional direction in FY 2001 for a Study of Avian Populations at the Nevada Test Site.

Human Genome..	**85,491**	**87,858**	**90,185**
▪ **Joint Genome Institute**	**61,822**	**57,200**	**57,200**

With the completion of the high quality DNA sequences of human chromosomes 16 and 19 in FY 2002 (DOE's share of the effort to sequence the human genome), the Joint Genome Institute (JGI) will continue to use its sequencing capacity to address the challenges of understanding the human genome, to address DOE mission needs and as a resource for our Nation's scientists. Past investments in DNA sequencing technology have continued to push costs down and throughput up making high-throughput DNA sequencing an even better scientific investment and a more effective research tool than ever for gene identification, finding gene regulatory elements, elucidating gene function, understanding evolutionary processes, developing the tools needed to predict cellular response to environmental stress, and performing the genetic manipulations needed to improve or alter gene function. In FY 2003 the JGI will focus on four main scientific areas:

- Microbial and Fungal Genomics
- Human Susceptibility
- Understanding the Regulatory Functions of DNA
- JGI as a National Resource

MICROBIAL AND FUNGAL GENOMICS – The JGI anticipates using 20% of its production DNA sequencing throughput on microbial and fungal genomics as well as a similar level of effort on functional genomics. The JGI will continue its efforts to understand the genomes and proteomes of microbial and fungal genomes important to DOE for:

- Carbon Sequestration - organisms that remove carbon from the environment
- Energy Sources - organisms that display novel photosynthetic or energy producing characteristics
- Bioremediation – organisms that act to clean up the environment
- Environmental Analysis - understanding how communities of microbes relevant to DOE missions interact to alter and detoxify their environment.
- Bioterrorism – organisms that could be used as or closely related to biothreat agents.

HUMAN SUSCEPTIBILITY - With the completion of the human DNA sequence we are now poised to understand how genes and the environment interact. This is especially important for understanding the role our genetic makeup plays in defining how we as individuals respond to

	(dollars in thousands)	
FY 2001	FY 2002	FY 2003

environmental stress in its many forms. This ties into many DOE programs, including the Low Dose Radiation Research program. The JGI will systematically analyze the human genome to first identify and then determine DNA sequence variation in the estimated ~5,000 human susceptibility genes. This will require an estimated 30% of the JGI production DNA sequencing capacity and the majority of its functional genomics resources. This information will be key to the Low Dose Radiation Research program with its complementary goal of understanding and characterizing genetic factors that contribute to individual sensitivity to energy-related insults.

UNDERSTANDING THE REGULATORY FUNCTIONS OF DNA - As a continuation of its responsibility to help understand the functioning of the human genome and as a key part of research on microbes for DOE energy and environmental needs, the JGI will focus on understanding the regulatory functions of DNA, such as gene regulation, characterization of DNA binding proteins and the full elucidation of gene promoters, enhancers and other regulatory mechanisms. Approximately 30% of the JGI's production DNA sequencing capacity will be required to meet this goal in addition to a proportion of its functional genomics resources. Model genomes currently under consideration for DNA sequencing and functional analysis to meet this goal include the *Ciona intestinalis*, chicken, and *Xenopus tropicalis*.

JGI AS A NATIONAL RESOURCE - A proportion, 20%, of the JGI's production DNA sequencing facility will be dedicated to the sequencing of a number of genomes or regions of interest as defined by the broader scientific community. This has proved to be a very productive and successful venture as demonstrated by previous "microbe months" in which large numbers of microbes were sequenced for JGI's scientific collaborators in a focused effort. The JGI will continue to seek guidance from its scientific advisors and to ensure that its efforts are of maximal benefit to DOE programs. Included in the JGI's DNA sequencing as a national resource is the completion of selected microbial and fungal genomes and a variety of projects in collaboration with and through grants from other agencies, such as the USDA.

Performance will be measured by (1) producing, with no increased funding, a total of approximately 8 billion base pairs of DNA sequence in FY 2003, a 100% increase in the number projected for FY 2001, and (2) establishing at least 30 diverse collaborations for high throughput DNA sequencing with scientists outside the JGI and with programs at other federal agencies.

	FY 2001	FY 2002	FY 2003
▪ **Tools for DNA Sequencing and Sequence Analysis**	**21,242**	**28,179**	**30,280**

BER continues to develop the tools and resources needed by the scientific, medical, and private sector communities to fully exploit the information contained in the first complete human DNA sequence. Unimaginable amounts of DNA sequencing, at dramatically increased speed and reduced cost, will be required in the future for medical and commercial purposes and to understand the information in the DNA sequence that has already been determined. BER continues to support research to further improve the reagents used in DNA sequencing and analysis; to decrease the costs of sequencing; to increase the speed of DNA sequencing; and new computational tools for genome-wide data analysis. Novel sequencing strategies such as microchannel capillary electrophoresis offer great promise for the every day sequencing needs of the future.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

Use of sequence information to understand human biology and disease will also require new strategies and tools capable of high-throughput, genome-wide experimental and analytic approaches. In FY 2003, BER will continue to increase efforts to develop high-throughput approaches for analyzing gene regulation and function.

▪ **Ethical, Legal, and Societal Issues (ELSI)**	**2,427**	**2,479**	**2,705**

The DOE and NIH human genome programs agreed at the outset to dedicate a fraction of their human genome program funding to understanding the ELSI issues associated with the genome program. DOE's ELSI research program represents 3 percent of the DOE human genome program. The DOE ELSI program supports research focused on issues of: (1) the use and collection of genetic information in the workplace especially as it relates to genetic privacy; (2) the storage of genetic information and tissue samples especially as it relates to privacy and intellectual property; (3) genetics and ELSI education; and (4) the ELSI implications of advances in the scientific understanding of complex or multi-genic characteristics and conditions.

A table follows displaying both DOE and NIH genome funding.

U.S. Human Genome Project Funding

	(dollars in millions)			
	Prior Years	FY 2001	FY 2002	FY 2003
DOE Total Funding (FY 87-00).............................	779.0	85.5	87.9	90.2
NIH Funding (FY 88-00).......................................	1,859.2	382.4	426.7[a]	TBD
Total U.S. Funding..	2,638.2	467.9	514.6	TBD

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Health Effects...	**17,616**	**13,640**	**14,251**
▪ **Functional Genomics Research**...	**14,417**	**13,640**	**14,251**

Scientific needs for functional genomics research - Functional genomics research capitalizes on our understanding and the manipulability of the genomes of model organisms, including Fugu (puffer fish), Ciona (sea squirt), and mouse, to speed understanding of human genome organization, regulation, and function. This research is a key link between human genomic sequencing, which provides a complete parts list for the human genome, and the development of information (a high-

[a] Estimate from NIH.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
tech owner's manual) that is useful in understanding normal human development and disease processes. The mouse continues to be a major focus of our efforts. It is an integral part of our functional genomics research effort. BER creates and genetically characterizes new mutant strains of mice that serve as important models of human genetic diseases and for understanding gene function. It also develops high-throughput tools and strategies to characterize these mutant strains of mice. This mouse genetics research provides tools useful to the entire scientific community for decoding the functionality of the human genome as human DNA sequence becomes available. Research to develop new strategies for using model organisms such as the mouse, Fugu, and *Ciona* to understand the function of human genes continues in FY 2003.			
▪ **Technology Development Research**	**3,199**	**0**	**0**
Technology development research is absorbed within the individual Life Sciences subprogram elements.			
SBIR/STTR increased with Life Sciences program increase	**0**	**4,876**	**5,331**
In FY 2001 $4,329,000 and $260,000 were transferred to the SBIR and STTR programs, respectively. FY 2002 and FY 2003 amounts are estimated requirements for the continuation of these programs.			
Total, Life Sciences	**188,469**	**192,573**	**210,878**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Structural Biology	
▪ Maintain structural biology research at near FY 2002 levels................................	-80
Molecular and Cellular Biology	
▪ Increase for Genomes to Life research on microbes that work to address DOE needs focused on understanding cellular processes and multicellular systems to a level where predictive simulation models can be developed to guide the use or development of microbial systems to solve DOE mission needs for energy use and production, waste cleanup, carbon sequestration, and biothreat reduction; and maintain microbial genomics and carbon sequestration research at near FY 2002 levels...	+15,252
▪ Maintains Low Dose Radiation Research at near FY 2002 levels.	-260
Total, Molecular and Cellular Biology..	+14,992

	FY 2003 vs. FY 2002 ($000)
Human Genome	
▪ High throughput sequencing to characterize the function and regulation of genes on human chromosomes 5, 16, 19 (the chromosomes worked on by DOE) and to use high throughput sequencing as a basic research tool in biology	+2,101
▪ Ethical, Legal, and Societal Issues program maintains funding at approximately 3% of total human genome funding	+226
Total, Human Genome	+2,327
Health Effects	
▪ Increase for research that develops strategies and tools to understand human gene function using model organisms.	+611
SBIR/STTR	
Increase in SBIR/STTR due to increase in research funding for the Life Sciences program.	+455
Total Funding Change, Life Sciences	+18,305

Climate Change Research

Mission Supporting Goals and Objectives

The goal of the Climate Change Research subprogram (previously the Environmental Processes subprogram) is to deliver relevant scientific knowledge that will enable scientifically-based predictions and assessments of the potential effects of greenhouse gas and aerosols emissions on climate and the environment. Research will reduce and resolve key uncertainties and provide the scientific foundation needed to predict, assess, and mitigate adverse effects of energy production and use on the environment through research in climate modeling and simulation, climate processes, carbon cycle and carbon sequestration, atmospheric chemistry, and ecological science.

The Climate Change Research subprogram supports four contributing areas of research: Climate and Hydrology; Atmospheric Chemistry and Carbon Cycle; Ecological Processes; and Human Interactions. The research is focused on understanding the physical, chemical, and biological processes affecting the Earth's atmosphere, land, and oceans and how these processes may be affected, either directly or indirectly, by energy production and use, primarily the emission of carbon dioxide from fossil fuel combustion. BER has designed and planned the research program to provide the data that will enable objective assessments of the potential for, and consequences of, global warming. The BER Climate Change Research subprogram (excluding the carbon sequestration element) represents DOE's contribution to the interagency U.S. Global Change Research Program proposed by President Bush in 1989 and codified by Congress in the Global Change Research Act of 1990 (P.L. 101-606). The National Institute for Global Environmental Change (NIGEC) is integrated throughout the subprogram (FY 2003 Request is $8,763,000).

A major emphasis of the Climate Change Research subprogram is on understanding the radiation balance from the surface of the Earth to the top of the atmosphere and how changes in this balance due to increases in the concentration of greenhouse gases in the atmosphere may alter the climate. Much of the research is focused on improving the quantitative models necessary to predict possible climate change at global and regional scales. Research in the Atmospheric Radiation Measurement (ARM) program will continue to focus on resolving the greatest scientific uncertainty in climate change prediction – the role of clouds and solar radiation. ARM seeks to develop a better quantitative understanding of how atmospheric properties, including the extent and type of cloud cover and changes in aerosols and greenhouse gas concentrations affect the solar and infrared radiation balance that drives the climate system. BER's Climate Modeling program develops advanced, fully coupled climate models and uses massively parallel supercomputers to simulate and predict climate and climate change, including evaluating uncertainties in climate models due to changes in atmospheric levels of greenhouse gases on decade-to-century time scales.

The Atmospheric Science program is focused on acquiring the data to understand the atmospheric processes that control the transport, transformation, and fate of energy-related chemicals and particulate matter emitted to the atmosphere. BER is emphasizing research on processes relating to new air quality standards for tropospheric ozone and particulate matter and relationships between air quality and climate change.

Research on the carbon cycle explores the movement of carbon on a global scale starting from natural and anthropogenic emissions to ultimate sinks in the terrestrial biosphere and the oceans. Experimental and modeling efforts primarily address the net exchange of carbon between major types of terrestrial ecosystems and the atmosphere. This research includes DOE's contribution to the Climate Change Research Initiative, an interagency effort on specific areas of climate change research in which substantial progress in understanding and modeling is expected over the next five years.

The BER carbon sequestration research funds basic research that seeks to exploit the biosphere's natural processes to enhance the sequestration of atmospheric carbon dioxide in terrestrial and marine ecosystems. It also seeks the understanding needed to assess the potential environmental implications of purposeful enhancement and/or disposal of carbon in the terrestrial biosphere and at the surface or deep ocean. The carbon sequestration activities include research to identify and understand the environmental and biological factors or processes that limit carbon sequestration in these systems and to develop approaches for overcoming such limitations to enhance sequestration. The research includes studies on the role of ocean and terrestrial microorganisms in carbon sequestration.

The Ecological Processes research is focused on experimental and modeling studies to understand and simulate the effects of climate and atmospheric changes on the biological structure and functioning of terrestrial ecosystems. The research also seeks to identify the potential feedback effect of ecosystem responses on climate and atmospheric composition. The research emphasizes major field studies of intact ecosystems using experimental manipulations of, for example, carbon dioxide and ozone concentrations and precipitation, and using data from these experiments to develop, test, and improve models for simulating and predicting ecosystem responses.

The Human Interactions research is focused on improving methods and models that can be used to assess the economic and societal costs and benefits of both human-induced climate change and possible response options or strategies for mitigating or adapting to climate change. It also includes support to archive and analyze global change data and make it available for use by the broader global change research community.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Climate and Hydrology	71,205	70,490	74,669	+4,179	+5.9%
Atmospheric Chemistry and Carbon Cycle	35,193	34,666	37,764	+3,098	+8.9%
Ecological Processes	11,352	12,383	13,888	+1,505	+12.2%
Human Interaction	7,928	8,054	8,084	+30	+0.4%
SBIR/STTR	0	3,329	3,554	+225	+6.8%
Total, Climate Change Research	125,678	128,922	137,959	+9,037	+7.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Climate and Hydrology	**71,205**	**70,490**	**74,669**
▪ **Climate Modeling**	**27,301**	**27,064**	**27,181**

Model based climate prediction provides the most scientifically valid way of predicting the impact of human activities on climate for decades to centuries in the future. BER will continue to develop, improve, evaluate, and apply the best coupled atmosphere-ocean general circulation models (GCMs) that simulate climate variability and climate change over these time scales. The goal is to achieve statistically accurate forecasts of future climate over regions as small as river basins using ensembles of model simulations. The ensembles will accurately incorporate the dynamic and thermodynamic feedback processes that influence climate, including clouds, aerosols, and greenhouse gas forcing. Current predictions are limited by the inadequacy of computational resources and uncertainties in the model representations of key small-scale physical processes, especially those involving clouds, evaporation, precipitation, and surface energy exchange. BER will address both the computational and scientific shortcomings through an integrated effort. Support will continue to be provided to acquire the high-end computational resources needed to complete ensembles of climate simulations using present and future models. BER will emphasize research to develop and employ information technologies that can quickly and efficiently work with large and distributed data sets of both observations and model predictions to produce quantitative information suitable for the study of regional climate changes. BER will continue to fund the multi-institutional research consortia established in FY 2001 to further the development of comprehensive coupled GCMs for climate prediction that are of higher resolution and contain accurate and verified representations of clouds and other important processes.

Performance will be measured: By the end of FY 2003, the program will increase the realism of the parallel coupled climate model by increasing the spatial resolution of the atmospheric model to 1.4 degrees and the ocean and sea ice model to approximately 0.7 degrees, which will be a higher resolution than any fully coupled climate model currently available to assess climate change. The capacity to produce multiple, long-term climate change scenarios for climate change research and assessment purposes will be enhanced by improvements in computing software and the development of improved algorithms needed to effectively exploit the new computing technology.

In FY 2003, BER will continue the partnership with the Advanced Scientific Computing Research program. This includes applying the computing resources for climate simulation and continuing climate model development and application through the use of collaboratory technologies. Additionally, BER will increase the emphasis on data assimilation methods so as to quickly make use of the high quality observational data streams provided by ARM, satellite and other USGCRP climate data programs to evaluate model performance.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

NIGEC will continue the support of research to evaluate the reliability of using isotopic signatures of trace gases in ice cores for interpreting climate variation and change in the past and the relationship between greenhouse gas concentrations and climate change (FY 2003 Request is $2,191,000).

	FY 2001	FY 2002	FY 2003
▪ **Atmospheric Radiation Measurement (ARM) Research**	**13,812**	**13,310**	**13,310**

The principal goal of the ARM scientific enterprise is to develop an improved understanding of the radiative transfer processes in the atmosphere and to formulate better parameterizations of these processes in climate prediction models, referred to as General Circulation Models (GCMs). ARM research supports about 50 principal investigators involved in studies of cloud physics and the interactions of solar and infrared radiation with water vapor and aerosols (including black soot). University scientists form the core of the ARM science team that networks with the broader academic community as well as with the scientists at the DOE National Laboratories and with federal scientists at NASA, NOAA, and DOD. ARM scientists pursue research as individuals and as members of teams and contribute both to the production of ARM data, e.g., as designers of cutting-edge remote sensing instrumentation, as well as consumers of the data produced at the three ARM sites. To facilitate the knowledge transfer from the ARM program to the premier modeling centers, the ARM program supports scientific "Fellows" at the NSF's National Center for Atmospheric Research, the NOAA's National Center for Environmental Prediction, and the European Center for Medium-Range Weather Forecasting in the U.K.

Performance will be measured: By the end of FY 2003, the program will deliver a more realistic representation of clouds for incorporation in atmospheric general circulation models. The improved representation of clouds will result in a 10% reduction in the uncertainty in calculations of the atmospheric energy budget and improve the accuracy and precision of climate models used to simulate and predict the effects on climate of atmospheric increases in energy-related greenhouse gases and aerosols.

	FY 2001	FY 2002	FY 2003
▪ **Atmospheric Radiation Measurement (ARM) Infrastructure**..	**27,371**	**27,371**	**31,441**

The Atmospheric Radiation Measurement (ARM) infrastructure program develops, supports, and maintains the three ARM sites and associated instrumentation. BER will continue to operate over two hundred instruments (e.g., multifilter shadowband radiometers for aerosol measurements, Raman Lidar for aerosol and cloud measurements, radar wind profiler systems, radar cloud measurement systems, sky imaging systems, arrays of pyranometers, pygeometers, and pyrheliometers for atmospheric and solar radiation measurements, and standard meteorological measurement systems for characterization of the atmosphere) at the Southern Great Plains site and will continue operations at the Tropical Western Pacific station and at the North Slope site in Alaska. The ARM program will continue to provide data to the scientific community through the ARM Archive.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

The ARM data streams will continue to be enhanced periodically by additional measurements at the ARM sites during intensive field campaigns referred to as Intensive Operation Periods (IOP). Ranging from two weeks to two months, the campaigns bring together teams of scientists testing cutting edge remote sensing instruments and coordinate measurements with airborne and satellite observations. The ARM sites have become major testbeds of research in atmospheric processes serving as scientific user facilities for hundreds of scientists from universities and government laboratories. For example, both DOD and NASA have used the ARM sites to "ground truth" their satellite instruments.

The increased funding will provide new instrumentation at the three ARM sites to measure the major components of the water cycle (including atmospheric water vapor, precipitation, evaporation, transpiration, soil water, and water runoff from land surfaces) and to measure energy-related aerosols and their radiative properties. The water cycle measurements will improve the climate models' parameterization of the coupling of radiation, cloud processes, and the land surface processes to reduce the current high uncertainty in predictions of precipitation patterns. The new knowledge gained from the water cycle study and aerosol measurements is important for climate studies. Additional staff and equipment will be provided to the ORNL ARM Data Archive to quality assure and distribute the data. The investment will increase the ARM users from about 680 to 800.

Performance will be measured by achieving a downtime of less than five percent for the principal ARM instruments and by the successful conduct of five IOPs across the three ARM sites.

▪ **Atmospheric Radiation Measurement (ARM)/Unmanned Aerial Vehicles (UAV)**..	**2,721**	**2,745**	**2,737**

The UAV program will conduct one major field campaign in conjunction with the ARM program to provide high altitude measurements of cloud properties and radiation budget.

Atmospheric Chemistry and Carbon Cycle.....................................	**35,193**	**34,666**	**37,764**
▪ **Atmospheric Science**	**14,582**	**12,510**	**12,571**

The Atmospheric Science projects acquire data to understand the atmospheric processes that control the transport, transformation, and fate of energy-related chemicals and particulate matter. Emphasis is placed on processes relating to new air quality standards for tropospheric ozone and particulate matter and relationships between air quality and climate change. Field and laboratory studies will continue to be conducted in both atmospheric chemistry and environmental meteorology and acquired data will be used to develop and validate predictive models of atmospheric processes. The research will include studies of chemical and physical processes affecting air pollutants such as sulfur and nitrogen oxides, tropospheric ozone, gas-to-particle conversion processes, and the deposition and resuspension of associated aerosols. It also includes studies to improve understanding of the meteorological processes that control the dispersion of energy-related chemicals and particulates in the atmosphere. Much of this effort involves multi-agency collaboration, and university scientists play key roles. New information will document both the contribution of energy production to regional haze in the U.S. and the relationship between urban and regional air pollution

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

processes and continental, intercontinental, and global scale phenomena. The information is essential for assessing the effects of energy production on air quality and will contribute to the evaluation of science-based options for minimizing the impact of energy production on visibility.

In FY 2003 BER will continue the Tropospheric Aerosol Program (TAP) to quantify the impacts of energy-related aerosols on climate, air quality, and human health. TAP will be closely coupled with other components of DOE's global change research, especially the Atmospheric Radiation Measurement (ARM) program. TAP will also be broadly coordinated with the air quality and global change research communities, including collaborations with the EPA, NASA, and NOAA and with the DOE Office of Fossil Energy's Airborne Fine Particulate Matter (PM) Research program. Regional patterns of aerosol distribution will be related to sources and sinks and the information will feed the models that simulate the impacts of aerosols on air quality and climate.

In FY 2003 the Atmospheric Sciences subprogram will, in general, focus on the evaluation of preliminary findings from field measurement campaigns in both atmospheric chemistry and environmental meteorology.

Performance will be measured by the extent, over five years, to which scientific results are incorporated into models to predict and assess air quality and radiative forcing of other energy-related greenhouse gases (such as ozone) and aerosols.

NIGEC will support research to quantify the effects of natural processes on atmospheric composition, including the exchange of energy-related trace gases between the atmosphere and the terrestrial biosphere (FY 2003 Request is $2,191,000).

▪ **Terrestrial Carbon Processes and Ocean Sciences**....................	**10,557**	**13,635**	**13,716**

BER will continue supporting the AmeriFlux program, which is a network of approximately 25 research sites where the net exchange of CO_2, energy, and water between the atmosphere and major terrestrial ecosystems in North America. These measurements are linked to field measurement campaigns across North America that will test how well point measurements represent larger areas and allow the estimation of carbon sources and sinks on a regional basis. This research supports the interagency Carbon Cycle Science Plan. The fluxes of other greenhouse gases, e.g., methane and nitrous oxide, will also be measured at several AmeriFlux sites.

BER will also continue research to refine and test carbon cycle models (based on mechanistic representations and simple carbon accounting). The models will be used to estimate potential carbon sequestration in response to changes in environmental factors, including climate.

Performance will be measured: By the end of FY 2003, the program will deliver quantitative estimates of net annual carbon sequestration in terrestrial ecosystems at five of the AmeriFlux network sites. The program will also deliver regional-scale estimates of the terrestrial carbon budget for three regions in North America such as the deciduous forest region of the eastern U.S.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

The focus of the ocean science element is on using microbiology tools to determine the linkages between the carbon and nitrogen cycles involving marine microbes. This research is conducted through partnerships between institutions with a tradition of research in oceanography (such as Skidaway Institute of Oceanography, U. of Washington, U. of Delaware, Rutgers University, U. of South Florida, Princeton University), and institutions traditionally serving minority students (such as Lincoln U., Howard U., Savannah State U., U. of Puerto Rico, and San Francisco State).

	FY 2001	FY 2002	FY 2003
▪ **Climate Change Research Initiative**	**0**	**0**	**2,920**

In FY 2003, the Administration will institute a new Climate Change Research Initiative (CCRI). The set of cross agency programs with a strong focus on outcomes and deliverables. The CCRI will focus on specific areas of research, including climate variation and change, carbon cycle, water cycle, atmospheric composition, and regional impacts. DOE, in conjunction with other USGCRP agencies, e.g., NASA, NOAA, NSF, etc., will contribute to one specific research area. The deliverables will be targeted at information useful to policy-makers, such as more reliable predictions of what the future climate would be under different greenhouse forcing scenarios and how much climate and land use changes will affect natural sources and sinks of carbon. DOE will participate in one of the specific research areas: understanding the North American Carbon Cycle (with NOAA, NSF, and USDA), which is identified as a priority need in the interagency Carbon Cycle Science Plan.

BER activities on the carbon cycle explore the movement of carbon on a global scale starting from natural and anthropogenic emissions to ultimate sinks in the terrestrial biosphere and the oceans. The AmeriFlux sites are essential to quantifying the net exchange of carbon between the atmosphere and major terrestrial ecosystems in North America and hence are essential to documenting the magnitude and variation in the North American carbon sink and how it is affected by interannual changes in climate. Experimental and modeling efforts primarily address the net exchange of carbon between major types of terrestrial ecosystems and the atmosphere.

BER will expand the facilities in the successful AmeriFlux program by including intensive measurements of additional parameters (e.g., above and belowground carbon stocks in roots, soil organic matter, aboveground tree trunks, stems leaves, litter, etc., and mortality of vegetation) and processes (e.g., photosynthesis, plant and microbial respiration rates, decomposition rate, carbonic acid weathering rate (which consumes CO_2), and vegetation growth rate) at the existing 25 AmeriFlux sites across North America and extensive measurements that transcend larger areas surrounding these sites, thereby allowing the estimation of carbon sources and sinks at landscape and regional scales. This information will provide a sound scientific basis for extrapolating carbon flux measurements at AmeriFlux sites to regional and continental scales and hence, improve estimates of both the magnitude of the North American carbon sink and the major terrestrial ecosystems that account for the sink. Fluxes of other greenhouse gases, including methane, nitrous oxide, and water vapor will also be measured at several AmeriFlux sites. The investment will increase the number of users from about 125 to 200.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Congressional Direction**..	**1,725**	**0**	**0**

Congressional direction in FY 2001 for the National Energy Laboratory in Hawaii and the Western States Visibility Study at New Mexico Tech.

▪ **Carbon Sequestration Research**	**8,329**	**8,521**	**8,557**

BER will continue support for one carbon sequestration research consortium, led by ORNL, PNNL, and ANL, and involving six collaboratory universities, that focuses on terrestrial sequestration ($3,000,000). The consortium develops the information to enhance the natural sequestration of carbon in terrestrial soils and vegetation. BER will also continue the support of research at universities and DOE laboratories on ocean carbon sequestration ($2,000,000). The focus of the research on terrestrial and ocean sequestration will continue to be on cellular and biogeochemical processes that control the rate and magnitude of carbon sequestration in terrestrial and oceanic systems, including the identification of pathways and processes that could be modified to enhance the net flow of carbon from the atmosphere to terrestrial plants and soils, and to the ocean surface and, ultimately, to the deep ocean. Also, BER will support the research needed to assess the environmental implications of enhancing carbon sequestration and storage in the ocean and in terrestrial systems. BER research on carbon sequestration in terrestrial ecosystems will improve the scientific understanding of mechanisms of sequestration and how to alter them to enhance sequestration. The Carbon Sequestration in Terrestrial Ecosystems (CSiTE) activity will conduct research that specifically examines those plant and soil processes that capture and retain carbon in chemical and physical forms that are resistant to decay. The data will inform new models for estimating carbon sequestration in terrestrial ecosystems. New technologies will be successfully developed by the BER-supported ocean carbon sequestration research to facilitate the export of carbon to the deep ocean and for re-mineralization of organic carbon at depth. Such technologies are vital to assessing accurately the potential of enhancing ocean carbon sequestration. Initial *in situ* experiments will be designed to determine the feasibility and potential environmental impacts of deep ocean injection of carbon dioxide (CO_2). Associated research will include determination of chemical reactions at depth, stability of products, and effects of those products on marine organisms.

Performance will be measured by applying an ecosystem framework to estimate annual rates of actual carbon gain by vegetation and soil, and enhanced sequestration will be estimated relative to baseline carbon quantities established for the range of ecosystems investigated by the CSiTE.

In FY 2003 university scientists will continue research on the effects of iron fertilization on plankton communities in the ocean and begin field experiments. The ocean surrounding Antarctica is the largest high-nutrient, low-chlorophyll region in the world. The joint DOE-NSF Southern Ocean Iron Enrichment Experiment (SoFEX) will help scientists understand the potential to enhance ocean carbon sequestration through iron enrichment.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

Performance will be measured by the analysis and publication of results from the Southern Ocean Iron Fertilization Experiment (SOFeX) which will study the export of particulate organic carbon below the mixed layer in high and low silicate waters following the experimental addition of iron to a large area of the surface ocean, delivering data necessary to understand and assess the efficacy of using iron fertilization to enhance carbon sequestration in the ocean.

Ecological Processes	**11,352**	**12,383**	**13,888**

BER will continue the six Free-Air Carbon Dioxide Enrichment (FACE) experiments at Maricopa, Arizona; Cedar Creek Natural History Area, Minnesota; Duke University, Durham, North Carolina; Rhinelander, Wisconsin; Mercury, Nevada; and Oak Ridge, Tennessee (ORNL) to improve understanding of the direct effects of elevated carbon dioxide and other atmospheric changes on the structure and functioning of various types of terrestrial ecosystems, including coniferous and deciduous forests, grasslands, and desert. Increasing emphasis will be on evidence of differential responses of plant species that may impact plant competition, succession, and productivity in terrestrial ecosystems. Research will explore changes, over time, in the elevated productivity of terrestrial plants exposed to elevated atmospheric carbon dioxide (CO_2) concentrations.

The long-term experimental investigation at the Walker Branch Watershed in Tennessee will continue to improve the understanding of the direct and indirect effects of alterations in the annual average precipitation on the functioning and structure of a southeastern deciduous forest ecosystem.

Both the FACE network and the Walker Branch Watershed represent scientific user facilities that have attracted scientists from both the academic community and government laboratories who use the facilities to develop new instrument methodologies and test scientific hypotheses related to ecosystem responses, including carbon sequestration, to climate and atmospheric changes.

Currently, the number of users conducting research at FACE facilities is affected by increased operational costs (e.g., cost of gases, electricity, security, and maintenance, replacement, and upgrade of instruments and other infrastructure at these facilities). The FY 2003 investment will provide the operational resources needed to effectively and efficiently maintain planned operation of the FACE facilities, thereby ensuring the facilities are maintained and operated in a way that benefits and attracts users and supports their needs. This investment in FACE facility operations will allow an increase in the number of users from about 200 in FY 2002 to 300 in FY 2003.

Performance will be measured by completion of a synthesis of data collected during 8-9 years of a unique experimental manipulation of precipitation received by a large-statured forest on the Oak Ridge reservation in a published book. This will include using the data collected in the experiment to evaluate (test) up to 15 ecosystem models for use in assessing forest responses to alterations in precipitation resulting from climate change.

NIGEC will support experimental studies to document how climate warming and increasing CO_2 levels in the atmosphere affect biophysical processes in terrestrial ecosystems (FY 2003 Request is $2,629,000).

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Human Interactions	**7,928**	**8,054**	**8,084**
▪ **Human Interactions**	**7,928**	**8,054**	**8,084**

The Integrated Assessment program, with a strong academic involvement, will continue to support research that will lead to better estimates of the costs and benefits of possible actions to mitigate global climate change. The new emphasis will be to improve the integrated assessment models to include other greenhouse gases as well as carbon dioxide, carbon sequestration, and international trading of emission permits. The models will better represent the efficiency gains and losses of alternate emission reduction plans, including market adjustments to inter-regional differences among relative energy prices, regulations, and production possibilities in the international arena. Integrated assessment models will be modified to include carbon sequestration as an alternative mitigation option. This representation will include both options to enhance natural carbon storage in the terrestrial biosphere, as well as engineering options, such as the capture of carbon dioxide and storage in geologic formations.

The research will include integrating a new land and ocean carbon sub-model in a large integrated assessment model. The submodel includes a detailed representation of direct human influence (mainly agriculture and forestry) on the terrestrial biosphere. In addition to providing a more accurate representation of the global carbon cycle, the change will ensure consistent accounting of carbon-sink projects and the carbon uptake that occurs as a result of other land-use change and the effects of climate change and carbon fertilization. A second integrated assessment model will be used to simulate the effect of 1) climate on crop yields and 2) the amount of crop and pasture land necessary to provide a) a sufficient diet in developing countries under climate change and b) the likely increase in dietary requirements as developing countries become richer.

NIGEC will support research to develop and test new methods involving the use of large regional databases and coupled climate-impact-economic models to conduct integrated assessments of the effects of climate change on regionally important resources in the U.S. (FY 2003 Request is $1,752,000).

The Information and Integration element stores, evaluates, and quality-assures a broad range of global environmental change data, and disseminates these to the broad research community. BER will continue the Quality Systems Science Center for the tri-lateral (Mexico, United States, and Canada) NARSTO (formally known as the North American Strategy for Tropospheric Ozone), a public partnership for atmospheric research in support of air quality management. The Center serves a diverse set of users, including academic and laboratory scientists and policy makers across North America.

The Global Change Education program supports DOE-related research in global environmental change for both undergraduate and graduate students, through the DOE Summer Undergraduate Research Experience (SURE), the DOE Graduate Research Environmental Fellowships (GREF), and collaboration with the NSF Significant Opportunities in Atmospheric Research and Science (SOARS) program.

	FY 2001	FY 2002	FY 2003
(dollars in thousands)			

Performance will be measured by sustaining the number, quality, and diversity of students enrolled in the program and by end-of-summer evaluations by students and their mentors.

	FY 2001	FY 2002	FY 2003
SBIR/STTR	**0**	**3,329**	**3,554**

In FY 2001 $3,160,000 and $188,000 were transferred to the SBIR and STTR programs, respectively. FY 2002 and FY 2003 amounts are estimated requirements for the continuation of these programs.

	FY 2001	FY 2002	FY 2003
Total, Climate Change Research	**125,678**	**128,922**	**137,959**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Climate and Hydrology	
▪ Climate modeling continued at near FY 2002 level.	+117
▪ The ARM increase in funding will support new instrumentation and ARM site staff for additional user support at the ARM sites and ARM data archive to allow the replacement and maintenance of ARM instruments and needed user support for scientists who use the ARM data or the ARM sites for field research.	+4,070
▪ Unmanned Aerial Vehicle (UAV) continued at near FY 2002 level.	-8
Total, Climate and Hydrology	+4,179
Atmospheric Chemistry and Hydrology	
▪ Atmospheric science continued at near FY 2002 level.	+61
▪ Terrestrial Carbon Process and Ocean Sciences continued at near FY 2002 levels.	+81
▪ BER will participate in the Climate Change Research Initiative research area to understand the North American carbon cycle by expanding the AmeriFlux network of research sites to allow regional extrapolation of net carbon exchange measurements.	+2,920
▪ Carbon Sequestration Research Consortia continued at near FY 2002 level.	+36
Total, Atmospheric Chemistry and Hydrology	+3,098

	FY 2003 vs. FY 2002 ($000)
Ecological Processes	
▪ The increase will support core operational costs at FACE sites to allow additional users at the sites by enabling the sites to be operated and maintained so as to attract a broader community of scientific users.	+1,505
Human Interactions	
▪ Human Interactions research is continued at near FY 2002 levels.	+30
SBIR/STTR	
Increase in SBIR/STTR due to increased research funding for Climate Change Research.	+225
Total Funding Change, Climate Change Research	+9,037

Environmental Remediation

Mission Supporting Goals and Objectives

The goal of the Environmental Remediation subprogram is to deliver relevant scientific knowledge that advances novel biotechnology solutions for environmental cleanup operations. Research on modified microbial processes that can stabilize radioactive waste and other toxic pollution in place, will contribute to remediation and restoration of contaminated environments at DOE sites and may also improve processes for recovery of valuable metals and production of fuel stocks.

BER's research in environmental remediation is focused on gaining improved 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. Research priorities are on bioremediation and on 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 how and where bioremediation may be applicable as a reliable, efficient, and cost-effective technique for cleaning up or containing metals and radionuclides in contaminated subsurface environments. In this subprogram, BER also includes basic research in support of pollution prevention, sustainable technology development and other fundamental research to address problems of environmental contamination.

In the NABIR program, research advances will continue to be made from molecular 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 activity 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 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 is exploring societal issues surrounding bioremediation research and promoting open and interactive communication with affected stakeholders to help ensure understanding and acceptance of bioremediation as a potential solution to remediating contaminants. All NABIR elements and EMSL activities have a substantial involvement of academic scientists.

Clean up research activities include a modest program in clean up research that will characterize the geologic, chemical, and physical properties that affect the rate and effectiveness of a variety of environmental remediation and waste-stream cleanup methods, including bioremediation; the Environmental Management Science Program, a cooperative program with the Office of Environmental Management to provide the science to solve the cleanup problems of the Nation's nuclear weapons complex; and ecological research conducted at the Savannah River Ecology Laboratory. The latter two activities are transferred in FY 2003 from Environmental Management to the Biological and Environmental Research program.

Within Facility Operations, support of the operation of the EMSL national user facility is provided for basic research that will underpin safe and cost-effective environmental remediation methods and technologies, other environmental science endeavors, and national security. Unique EMSL facilities, such as the Molecular Science Computing Facility, the High-Field Mass Spectrometry Facility, and the High-Field Magnetic Resonance Facility, are 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, transport of contaminants in subsurface groundwater and vadose zone sediments, and atmospheric chemical reactions that contribute to changes in the atmospheric radiative balance.

BER's William R. Wiley Environmental Molecular Sciences Laboratory will use its capabilities to expand its collaborations in the areas of structural biology and functional genomics. The number of users undertaking structural biology research will also increase.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Bioremediation Research	27,538	27,997	30,700	+2,703	+9.7%
Clean Up Research	45,449	47,502	38,190	-9,312	-19.6%
Facility Operations	31,248	37,333	37,948	+615	+1.6%
SBIR/STTR	0	1,569	2,692	+1,123	+71.6%
Total, Environmental Remediation	104,235	114,401	109,530	-4,871	-4.3%

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
Bioremediation Research	**27,538**	**27,997**	**30,700**
▪ **NABIR and Bioremediation Research**	**21,571**	**22,042**	**24,720**

NABIR will increase the understanding of the intrinsic bioremediation (natural attenuation) of DOE relevant metal and radionuclide contaminants, as well as of manipulated, accelerated bioremediation using chemical amendments. Laboratory and field experiments will be conducted to explore the fundamental mechanisms underlying chemical processes and complexation/transformation of contaminants. The NABIR Field Research Center is in operation at the Oak Ridge National Laboratory. Field site characterization of this Field Research Center and distribution of research samples to investigators will continue. In FY 2003, science elements in the NABIR program include fundamental research in the following subjects: (1) Biotransformation (microbiology to elucidate the mechanisms of biotransformation of metals and radionuclides); (2) Community Dynamics and Microbial Ecology (structure and activity of subsurface microbial communities); (3) Biomolecular Science and Engineering (molecular and structural biology to enhance the understanding of bioremediation and identify novel remedial genes); (4) Biogeochemical Dynamics (dynamic relationships among *in situ* geochemical, geological, hydrological, and microbial processes); (5) Assessment (measuring and validating the biological and geochemical processes of bioremediation); and (6) Acceleration (developing effective methods for accelerating and optimizing bioremediation rates). University scientists continue to form the core of the NABIR science team that networks with the broader academic community as well as with scientists at the National Laboratories and at other agencies.

The NABIR Field Research Center (FRC) at Oak Ridge is characterizing the subsurface water flow and contaminant transport, and modeling subsurface flow, transport, and biogeochemistry at the FRC. Initial results will be published in FY 2002 and will help determine the efficacy of removing nitrate and injecting electron donors to precipitate and, therefore, immobilize uranium. The NABIR program will take advantage of the newly completed genomic sequence of three important metal and radionuclide-reducing microorganisms to study the regulation and expression of genes that are important in bioremediation. Knowledge of the regulation of genes involved in metal-reduction, such as the cytochromes, will determine the effect of co-contaminants, such as nitrate or other metals and radionuclides on the ability of microorganisms to immobilize the metals and radionuclides. Researchers working on *Geobacter sulfurreducens*, *Desulfovibrio vulgaris,* and *Shewanella oneidiensis* will be able to use the genetic sequence and laboratory techniques such as micro-arrays to determine the enzymatic pathways for the reduction of uranium.

In FY 2003, research will focus on the completion of two critical field experiments at the NABIR FRC near the Y-12 area at the Oak Ridge Reservation. The first experiment will use "push-pull" technology to probe the structure and function of undisturbed microbial communities in the subsurface contaminated with uranium and nitrate. This will be the first time this new technology has been tested in a radionuclide-contaminated site. The second experiment will provide valuable information on the use of bioremediation to remove uranium from groundwater in which nitrate is a co-contaminant--a common problem at DOE sites.

Performance will be measured: By the end of FY 2003, the program will demonstrate whether certain nutrient additions stimulate subsurface microorganisms to immobilize uranium, thereby reducing its concentration and transport in soil water and groundwater. The demonstration will be in a contaminated subsurface environment where the co-contaminant nitrate is also present and will confirm the potential of biotechnology for environmental remediation of radionuclides**.**

Performance will also be measured by the successful demonstration, in partnership with EM-50, of the reliability of using new biologically based technologies for monitoring radionuclide contaminants and the microbial communities that can bioremediate those contaminants. These include antibody-based sensors for detecting uranium and certain metals, as well as nucleic acid based technologies for assessing the structure and functioning of microbial communities in contaminated environments.

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		
▪ **General Plant Projects (GPP)**	**4,800**	**4,791**	**4,811**

The 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.

The effort will continue rehabilitation and upgrade of research facilities in the 300 area of the PNNL, including beginning the replacement of sanitary water piping in a 40 year old building used for research, refurbishing 20-year old laboratory space, and reconfiguring space in a 45 year old building to better accommodate current scientific research projects.

	FY 2001	FY 2002	FY 2003
▪ **General Purpose Equipment (GPE)**	**1,167**	**1,164**	**1,169**

The General Purpose Equipment (GPE) funding will continue to provide 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.

	FY 2001	FY 2002	FY 2003
Clean Up Research	**45,449**	**47,502**	**38,190**
▪ **Clean Up Research**	**1,502**	**2,452**	**2,463**

The modest program in clean up research will characterize the geologic, chemical, and physical properties that affect the rate and effectiveness of a variety of environmental remediation and waste-stream cleanup methods, including bioremediation.

Research will support laboratory and field studies at universities and DOE laboratories to identify and characterize the biophysical and chemical properties of environmental pollutants in contaminated environments and waste streams, especially how those properties influence the efficacy of various remediation and waste-stream cleanup methods. In FY 2003, research in in-situ approaches is continued on challenging problems of mixed wastes containing complex mixtures of organic wastes, metals, and radionuclides.

Much of this research will be conducted in collaboration with the Office of Environmental Management (EM).

	FY 2001	FY 2002	FY 2003
▪ **Environmental Management Science Program**	**36,067**	**37,050**	**29,886**

The goal of the Environmental Management Science Program (EMSP), transferred in FY 2003 from EM to the BER program, is to support basic research that improves the science base underpinning the clean up of DOE sites. Traditional clean up strategies may not work or be cost effective for many of the challenges that threaten the successful closure of DOE sites. The EMSP, through its support of basic research aims to develop and validate technical solutions to complex problems,

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

provide innovative technical solutions where there are none, and lead to future risk reduction and cost and time savings. The goal of the EMSP is to support basic research projects that could lead to specific demonstration projects and new clean up strategies. It is the intent or the expectation of the EMSP that the basic research projects funded offer the potential of having specific practical applications or specific timelines for the development of applications for waste cleanup. Basic research that addresses the broad technical and scientific uncertainties associated with DOE site clean up will continue to be funded through a process of competitive peer review. The most scientifically meritorious research proposals and applications will be funded based on availability of funds and programmatic relevance to ensure a complete and balanced research portfolio that addresses DOE needs. The Office of Environmental Management will be consulted. Research will be funded at universities, national laboratories, and at private research institutes and industries.

	FY 2001	FY 2002	FY 2003
▪ **Savannah River Ecology Laboratory**	**7,880**	**8,000**	**5,841**

This activity supports, through a cooperative agreement with the University of Georgia, a long-term (40+ years) ecological research activity aimed at reducing the cost of clean up and remediation while ensuring biodiversity at the restored environment. Peer-reviewed research will be supported to understand contaminant behavior in the environment, to elucidate molecular mechanisms of toxicity from environmental contaminants, to develop cheaper and more environmentally sound remediation approaches, and to assess the ecological risks of environmental contaminants. Characterizing and understanding the impacts of environmental contamination on intact, living ecosystems is a complex and long-term process since the research is dependent on natural cycles of growth, reproduction, and normal environmental variation. A sustained investment is required to understand the complex interactions of ecosystems with environmental contaminants.

	FY 2001	FY 2002	FY 2003
Facility Operations: William R. Wiley Environmental Molecular Sciences Laboratory (EMSL)	**31,248**	**37,333**	**37,948**
▪ **Operating Expenses**	**26,798**	**34,339**	**35,959**

The EMSL is a scientific user facility focused on conducting interdisciplinary, collaborative research in molecular-level environmental science. Operating funds are essential to allow the EMSL to operate as a user facility, and are used for maintenance of buildings and instruments, utilities, staff support for users, environment, safety and health compliance activities, and communications. With over 100 leading-edge instruments and computer systems, the EMSL annually supports approximately 1000 users. University scientists form the core of the EMSL science team that networks with the broader academic community as well as with scientists at other agencies. EMSL users have access to unique instrumentation for environmental research, including the 512-processor, high performance computer system, a suite of nuclear magnetic resonance spectrometers ranging from 300 MHz to 900 MHz, a suite of mass spectrometers, including an 11.5 Tesla high performance mass spectrometer, laser desorption and ablation instrumentation, ultra-high vacuum scanning tunneling and atomic force microscopes, and controlled atmosphere environmental chambers.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

The new 3-4 Teraflop high performance computer is being used for model code development in molecular geochemistry and biogeochemistry, and numerical modeling of reactive transport in the subsurface, chemical processing and catalysis, aerosol formation and chemical transformations and climate modeling and simulation. The computer also assists the EMSL focus on structural genomics.

Performance will be measured by (1) initiating operation of a new high performance computer at the EMSL and (2) having unscheduled operational downtime on EMSL instrumentation and computational resources not to exceed 10 percent.

	FY 2001	FY 2002	FY 2003
▪ **Capital Equipment**	**4,450**	**2,994**	**1,989**

Capital equipment support for the EMSL enables instrument modifications needed by collaborators and external users of the facility as well as the purchase of state-of-the-art instrumentation to keep EMSL capabilities at the leading edge of molecular-level scientific research. Increased capital equipment funding ($3,000,000) in FY 2001 supported the upgrade of user capabilities through the acquisition of additional mass spectrometers and Nuclear Magnetic Resonance (NMR) spectrometers for structural biology research.

	FY 2001	FY 2002	FY 2003
SBIR/STTR	**0**	**1,569**	**2,692**

In FY 2001 $1,242,000 and $74,000 were transferred to the SBIR and STTR programs, respectively. FY 2002 and FY 2003 amounts are estimated requirements for the continuation of these programs.

	FY 2001	FY 2002	FY 2003
Total, Environmental Remediation	**104,235**	**114,401**	**109,530**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Bioremediation Research	
▪ Increased support for bioremediation research to expand research on microbially-mediated transformations of metals and radionuclides and how these processes can be altered to immobilize contaminants in place in subsurface environments.	+2,678
▪ General Plant Projects continued at near FY 2002 level.	+20
▪ General Purpose Equipment continued at near FY 2002 level.	+5
Total, Bioremediation Research	+2,703

	FY 2003 vs. FY 2002 ($000)
Clean Up Research	
▪ Clean Up Research continued at near FY 2002 level.	+11
▪ Environmental Management Science program transferred in FY 2003 from the Office of Environmental Management to the BER program continued at a reduced level.	-7,164
▪ Savannah River Ecology Laboratory transferred in FY 2003 from the Office of Environmental Management to the BER program continued at a reduced level.	-2,159
Total, Clean Up Research	-9,312
Facility Operations	
▪ EMSL funding increase provides for additional user support.	+615
SBIR/STTR	
▪ SBIR/STTR increases due to increase in research funding for the Environmental Remediation program.	+1,123
Total Funding Change, Environmental Remediation	-4,871

Medical Applications and Measurement Science

Mission Supporting Goals and Objectives

The goal of the Medical Applications and Measurement Science subprogram is to deliver relevant scientific knowledge that will lead to innovative diagnostic and treatment technologies for human health. The research builds on unique DOE capabilities in physics, chemistry, engineering, and biology. Research will lead to new metabolic labels and imaging detectors for medical diagnosis; tailor-made radiopharmaceutical agents and beam delivery systems for treatment of inoperable cancers; and the ability to predict structure and behavior of cells and tissues to better engineer targeted drugs, biosensors, and medical implants. The basic research technologies growing out of this program offer applications for study, detection, diagnosis and early intervention of biochemical, bacterial, and viral health risks of biological, and/or gross environmental insults such as bioterrorism.

The modern era of nuclear medicine is an outgrowth of the original charge of the Atomic Energy Commission (AEC), "to exploit nuclear energy to promote human health." From the production of a few medically important radioisotopes in 1947, to the development of production methods for radiopharmaceuticals used in standard diagnostic tests in millions of patients throughout the world, to the development of ultra-sensitive diagnostic instruments, e.g. the PET (positron emission tomography) scanner, the medical applications program has led and continues to lead the field of nuclear medicine.

Today the program seeks to develop new applications of radiotracers in diagnosis and treatment in light of the latest concepts and developments in genomic sciences, structural and molecular biology, computational biology and instrumentation. Using non-invasive technologies and highly specific radiopharmaceuticals, BER is ushering in a new era of brain mapping, and highly specific disease diagnostics. New tools will enable the real-time imaging of gene expression in a developing organism.

Research capitalizes on the National Laboratories' unique resources and expertise in biological, chemical, physical, and computational sciences for technological advances related to human health. The National Laboratories have highly sophisticated instrumentation (neutron and light sources, mass spectroscopy, high field magnets), lasers and supercomputers, to name a few, that directly impact research on human health. Research is directed to fundamental studies in medical imaging, biological and chemical sensors, laser medicine and informatics. This research is highly complementary to and coordinated with clinical research at the National Institutes of Health (NIH) and to basic research in the NIH intramural and extramural programs.

Measurement Science research emphasizes new sensor instrumentation for cleanup efforts and new imaging instrumentation having broad application in the life and medical sciences.

The Medical Applications and the Measurement Science subprogram continues a substantial involvement of academic scientists along with the scientists in the National Laboratories.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Medical Applications	87,276	113,825	38,701	-75,124	-66.0%
Measurement Science	5,911	5,935	5,961	+26	+0.4%
SBIR/STTR	0	3,239	1,186	-2,053	-63.4%
Total, Medical Applications and Measurement Science	93,187	122,999	45,848	-77,151	-62.7%

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
Medical Applications	**87,276**	**113,825**	**38,701**
▪ **Boron Neutron Capture Therapy (BNCT) and novel cell-directed cancer therapies**	**10,082**	**9,941**	**4,870**

In FY 2003, funding for the followup of all patients treated in the human clinical trials of boron neutron capture therapy (BNCT) at Brookhaven National Laboratory and the Massachusetts Institute of Technology will be completed with the transfer of clinical technology to the National Cancer Institute. The basic drug development research for BNCT will evolve into a new program of innovative approaches to cell-targeted ablation therapy for cancer with in-vivo radiation techniques. Success of the program will depend on key partnerships with scientists from the National Laboratories and academia. The emphasis of this program will be on the therapeutic use of ionizing radiation that may be achieved with radionuclide therapy and novel methods of tumor targeting. The specific goals include the development of novel therapeutic agents and delivery techniques to target and treat cancer at the cellular level. Research will address such complex challenges as chemical ligand synthesis, tumor-targeting, and dosimetry.

Overall program objectives include: (1) techniques to ensure highly selective tumor-targeting by the proposed therapeutic agents; (2) efficient screening techniques for selecting candidate therapeutic agents for in-vivo testing; (3) research suggesting a reasonable likelihood of success for in-vivo targeting of primary tumors and their metastases in pre-clinical animal trials; (4) reliable approaches for dosimetry calculations to normal tissues and to tumor sites based on 3-dimensional modeling; (5) measurement techniques for accurately assessing the success of tumor-targeting in vivo; and (6) measurement techniques for assessing therapy effects in vivo at the molecular, cellular and metabolic levels.

Performance will be measured by the number of tumor therapeutic agents that perform sufficiently well in pre-clinical evaluations over five years to deserve consideration for clinical trials by NIH and/or private industry.

(dollars in thousands)

	FY 2001	FY 2002	FY 2003

Performance will be measured: By the end of FY 2003, all the boron neutron capture therapy (BNCT) clinical trials will be completed with clinical data collection, and transfer of the clinical data to the National Cancer Institute as the foundation for an advanced treatment modality for cancer.

	FY 2001	FY 2002	FY 2003
▪ **Radiopharmaceutical Design and Synthesis**	**26,065**	**24,340**	**24,445**

BER will support research on radiopharmaceutical design and synthesis using concepts from genomics as well as computational biology and structural biology. BER will continue research into radiolabeling of monoclonal antibodies for cancer diagnosis and new radiotracers for the study of brain and heart function. Molecules directing or affected by homeostatic controls always interact and, thus, are targets for specific molecular substrates. The substrate molecules can be tailored to fulfill a specific need and labeled with appropriate radioisotopes to become measurable in real time in the body on their way to, and during interaction with their targets, allowing the analysis of molecular functions in the homeostatic control in health and disease. The function of radiopharmaceuticals at various sites in the body is imaged by nuclear medical instruments, such as, gamma ray cameras and positron emission tomographs (PET). This type of imaging refines diagnostic differentiation between health and disease at the molecular/metabolic levels as well as often leading to more effective therapy. If labeled with high energy-emitting radioisotopes, the substrate molecules, carrying the radiation dose may be powerful tools for targeted molecular therapy especially of cancer.

BER will also develop nuclear medicine driven technologies to image mRNA transcripts in real time in tissue culture and whole animals. Currently the expression of endogenous genes in animals (including humans) cannot be imaged, at least not directly. However, given the astounding pace of biotechnology development, such imaging is an attainable goal. This research includes an emphasis on nucleic acid biochemistry, radioactive ligand synthesis and macromolecular interactions. It addresses the functional consequences of gene expression by targeting and perturbing the activity of a particular gene in living cells or animals. It also develops new biological applications using optical and radionuclide imaging devices for imaging specific gene expression in real time in both animals and humans. Methods such as combinatorial chemistry techniques will be used to develop antisense radiopharmaceuticals that hybridize DNA probes to RNA transcripts in highly specific ways to block their activity or function. Molecular signal amplification methods that work in vivo at the mRNA level will be developed. Drug-targeting technology will be developed to such an extent that the various biological barriers can be safely surmounted in vivo. The research will evaluate the clinical potential of real-time imaging of genes at work in cells, tissues, and whole organisms, including humans. This information will have applications ranging from understanding the development of a disease to the efficacy of treatments for the disease. This new technology will strongly impact developmental biology, genome research, and medical sciences.

Performance will be measured: By the end of FY 2003, through radiopharmaceutical and molecular nuclear medicine research, three positron emission tomography (PET) radiotracers with precise cellular, subcellular, and molecular targeting capability will be developed as potential imaging agents for nuclear medicine research and clinical use to study brain disorders due to substance abuse and

	(dollars in thousands)	
FY 2001	FY 2002	FY 2003

mental illnesses (such as Alzheimer's and Parkinson's diseases), cancer diagnosis and treatment, heart-function-related ailments, therapeutic gene expression in the whole animals, and for monitoring progress to therapy.

	FY 2001	FY 2002	FY 2003
▪ **Multimodal Imaging Systems and Medical Photonics**..................	**10,004**	**9,753**	**9,386**

In FY 2003, BER will emphasize support in multimodal imaging systems for study of human brain function and continue to explore the combination of nuclear medicine imaging systems with magnetic resonance imaging. The research will continue to develop innovative imaging instrumentation and will transfer the relevant technology into clinical medicine. PET and MRI instrumentation systems will be developed to image small animals with high resolution. The program will continue to support research in brain imaging including substance abuse, mental illness, Parkinson's disease, Alzheimer's disease, and studies of neurochemical metabolism.

Performance will be measured: By the end of FY 2003, 1-3 advanced radiotracer imaging camera devices, that approach the fundamental limits of spatial resolution and detector sensitivity, will be available to detect breast cancer to differentiate benign as compared to malignant growth, and will measure biological function in small animals as the models of human disease.

BER will also expand its research program at the National Laboratories by capitalizing on their unique resources and expertise in the biological, physical, chemical, and computational, sciences to develop new research opportunities for technological advancement related to human health. Due to the medical nature of the program, all research activities are joint activities between the National Laboratories and medical research centers. The program emphasizes biomedical imaging, novel sensing devices, spectroscopy, and related informatics systems. It will advance fundamental concepts, create knowledge from the molecular to the organ systems level, and develop innovative processes, instruments, and informatics systems to be used for the prevention, diagnosis, and treatment of disease and for improving health care in the Nation. Emphasis is placed on:

Biomedical Imaging – is the development of novel medical imaging systems. BER will combine optical imaging with other traditional medical imaging systems such as MRI, PET, and SPECT (single photon emission computed tomography) and will develop small imaging systems that image in real-time under natural physiological conditions. A major objective is improving the reliability and cost-effectiveness of medical imaging technologies. Technology and detector systems will be developed to capitalize on recent findings of the human genome project that will enable imaging of gene expression in real time that will have a critical impact on biomedical research and medical diagnosis. The BER program has played a leading role in the development of new positron emission tomography (PET) instrumentation as well as new chemistries for applying PET to diagnosis of cancer and other diseases. A high priority is placed on transfer of the new PET technologies into clinical research and practice.

Medical Photonics – is the development of advanced optical systems, including lasers, that will enhance the monitoring, detection, and treatment of disease. BER will expand its development of an artificial retina that can convert light signals into physiological electrical impulses.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

Smart Medical Instrumentation – is the development and fabrication of "smart" medical instruments that can operate within the body either remotely or independently to monitor, detect, and treat various medical dysfunctions. This includes the development and fabrication of biological sensors that can be used to detect or monitor various physiological functions and disease in the body in real-time.

The ultimate goal of the program is to support basic research and technology development that will ultimately lead to the development of technology that can be transferred to the National Institutes of Health for clinical testing or to industry for further commercial development. This research takes advantage of unique resources at DOE facilities and is highly complementary to and coordinated with clinical research at the National Institutes of Health (NIH) and to basic research in the NIH intramural and extramural programs.

Performance will be measured by the enhancement of micro-PET and micro-CT scanners so that these unique and powerful tools can be used to enhance basic biomedical research in medical centers, leading to improved human health care, and over the next five years, mutually beneficial research partnerships between the BER Advanced Medical Technology Program and the Intramural Clinical Research Programs at the National Institutes of Health (NIH) will deliver two new biosensor and infrared thermography technologies using the physical science expertise of the DOE national laboratories. The technologies will aid in the detection of disease at an early stage.

	FY 2001	FY 2002	FY 2003
▪ **Congressional Direction**..	**41,125**	**69,791**	**0**

Congressional direction in FY 2001 for School of Public Health, University of South Carolina; Nuclear Medicine and Cancer Research Capital Program, University of Missouri-Columbia; Discovery Science Center in Orange County, California; Children's Hospital Emergency Power Plant in San Diego; Center for Science and Education at the University of San Diego; Bone Marrow Transplant Program at Children's Hospital Medical Center Foundation in Oakland, CA; North Shore Long Island Jewish Health System, New York; Museum of Science and Industry, Chicago; Livingston Digital Millenium Center, Tulane University; Center for Nuclear Magnetic Resonance, University of Alabama-Birmingham; Nanotechnology Engineering Center at the University of Notre Dame of South Bend, Indiana; National Center for Musculoskeletal Research, Hospital for Special Surgery, New York; High Temperature Super Conducting Research and Development, Boston College; Positron Emission Tomography Facility, West Virginia University; Advanced Medical Imaging Center, Hampton University; Child Health Institute of New Brunswick, New Jersey; Linear Accelerator for University Medical Center of Southern Nevada; Medical University of South Carolina Oncology Center; National Foundation for Brain Imaging; Science and Technology Facility at New Mexico Highlands University; and Inland Northwest Natural Resources Research Center at Gonzaga University.

(dollars in thousands)

FY 2001	FY 2002	FY 2003

Congressional direction in FY 2002 for Positron Emission Tomography Center at the University of South Alabama; Gulf Coast Cancer Center and Research Institute; Center for Nuclear Magnetic Resonance Imaging at the University of Alabama Birmingham; University of South Alabama research, in cooperation with industry and the Cooperative Research Network of the National Rural Electric Cooperative Association, on a fuel cell powered home using the Smart Energy Management Control System; Library and Regional Resource Learning Center at Spring Hill College; South Alabama Medical Education Outreach Program; University of Florida Genetics Institute; Linear Accelerator for the Baystate Medical Center; Cancer Institute at New Jersey; Institute for Molecular Biosciences at the University of Arizona; Stanley Scott Cancer Center at Louisiana State University; Infotonics Center of Excellence in Rochester New York; Joint Collaboration on Advanced Nanotechnology and Sensors with the University of New Orleans, Louisiana State University, and Louisiana Tech; Breast Cancer Program at the North Shore-Long Island Jewish Health System; Functional Magnetic Resonance Imaging Machine at the University of Texas at Dallas and the University of Texas Southwestern Medical Center's Center for Brain, Cognition, and Behavior; Integrated Environmental Research and Services Program at Alabama A&M University; Energy Efficiency Initiative at the Carolinas Health Care System; Multidisciplinary Research Facility at the College of Engineering, University of Notre Dame; Linear Accelerator for the Burbank Regional Cancer Center in Fitchburg, Massachusetts; Hampshire College's National Center for Science Education; Audubon Biomedical Science and Technology Park at Columbia University; McFadden Science Center at Texas Wesleyan University; Emergency Power Supply System at Cedars-Sinai Medical Center; Rush-Presbyterian-St. Luke's Medical Center; Nanoscience Facility at Purdue University; Julie and Ben Rogers Cancer Institute; School of Public Health at the University of South Carolina; Continued Development of the Life Science Building at Brown University; Environmental Modeling at the University of North Carolina at Chapel Hill; Renovation of the Science, Technology, and Engineering Research Complex at Jackson State University; PowerGrid Simulator at Drexel University and the New Jersey Institute of Technology; Positron Emission Tomography Facility at West Virginia University; Linear Accelerator for the University Medical Center of Southern Nevada; Research Foundation of the University of Nevada-Las Vegas; University of Nevada-Las Vegas for Continued Study of the Biological Effects of Exposure to Low-level Radioactivity; Biomolecular Nuclear Magnetic Resonance Instrument at the Medical University of South Carolina; Oncology Center of the Medical University of South Carolina; National Center of Excellence in Photonics and Microsystems in New York; Institute of Comparative Genomics at the American Museum of Natural History; Inland Northwest Natural Resources Center at Gonzaga University; Hall of Paleontology at the Field Museum; Center for Catalysis at Iowa State University; Human Genome Project at the University of Southern California; Biomedical Research at Creighton University; Child Health Institute of New Brunswick, New Jersey; Oregon Renewable Energy Center; Superconductor Research at Boston College; Natural Renewable Energy Laboratory in Hawaii; Rochester Institute of Technology Microelectronics Technology Program; Operations and Capital Investment at the Mental Illness and Neuroscience Discovery Institute; and University of Missouri-Columbia to Expand the Federal Investment in the University's Nuclear Medicine and Cancer Research Capital Program.

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		

Measurement Science	**5,911**	**5,935**	**5,961**

BER will continue research on new sensor instrumentation for characterizing the chemical composition of contaminated subsurface environments in support of the Department's environmental cleanup efforts of highly radioactive chemical wastes.

The research will include the development of new environmental sensors that are better, faster, and more economical than existing laboratory techniques. New field-based sensors that take advantage of novel biotechnologies will be ready for deployment. The new sensors will include antibody and nucleic acid approaches that have precedence in other applications but will be new to bioremediation at DOE legacy sites.

Research into new imaging instrumentation for life sciences and biomedical sensor applications will be continued. Capital equipment funds will be used for research to develop new instrumentation having broad application in the life and medical sciences. BER will continue research on medical applications of laser technology at the National Laboratories and at universities.

SBIR/STTR	**0**	**3,239**	**1,186**

In FY 2001 $2,357,000 and $143,000 were transferred to the SBIR and STTR programs, respectively. FY 2002 and FY 2003 amounts are estimated requirements for the continuation of these programs.

Total, Medical Applications and Measurement Science	**93,187**	**122,999**	**45,848**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Medical Applications	
▪ Boron Neutron Therapy (BNCT) program is completed and research on novel cell-directed cancer therapies is initiated	-5,071
▪ Radiopharmaceutical Design and Synthesis and Multimodal Imaging Systems and Medical Photonics are continued at near FY 2002 levels.	-262
▪ Decrease due to Congressional direction in FY 2002.	-69,791
Total Funding Change, Medical Applications	-75,124
Measurement Science	
▪ Measurement Science will continue at near FY 2002 levels	+26

	FY 2003 vs. FY 2002 ($000)
SBIR/STTR	
▪ SBIR/STTR decreases due to decrease in research funding for the Medical Applications and Measurement Science program	-2,053
Total Funding Change, Medical Applications and Measurement Science	-77,151

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Construction

Mission Supporting Goals and Objectives

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

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Construction	2,495	11,405	0	-11,405	--

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
Construction	**2,495**	**11,405**	**0**

- The Laboratory for Comparative and Functional Genomics at Oak Ridge National Laboratory will provide a modern gene function research facility to help understand the function of newly discovered human genes, to support DOE research programs and to provide protection for the genetic mutant mouse lines created during the past 50 years. This new facility will replace a 50-year old animal facility with rapidly escalating maintenance costs still in use at Oak Ridge.

  Performance will be measured: By the end of FY 2003, construction of the Center for Comparative and Functional Genomics at Oak Ridge National Laboratory will be completed on schedule.

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Construction	
▪ Full funding for the construction of the Laboratory for Comparative and Functional Genomics provided in FY 2002.	-11,405

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
General Plant Projects	8,094	4,791	4,811	+20	+0.4%
Capital Equipment	44,538	17,543	17,047	-496	-2.8%
Total Capital Operating Expenses	52,632	22,334	21,858	-476	-2.1%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp- riations	FY 2001	FY 2002	FY 2003	Unapprop- riated Balance
01-E-300, Laboratory for Comparative and Functional Genomics, ORNL	13,900	0	2,495	11,405	0	0
Total, Construction		0	2,495	11,405	0	0

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp- riations	FY 2001	FY 2002	FY 2003	Acceptance Date
DNA Repair Protein Complex Beamline, ALS	4,490	0	4,490	0	0	FY 2001
Total, Major Items of Equipment		0	4,490	0	0	

Basic Energy Sciences

Program Mission

Basic Energy Sciences (BES) and its predecessor organizations have supported a program of fundamental research focused on critical mission needs of the Nation for over five decades. The federal program that became BES began with the research effort that was initiated to help defend our Nation during World War II. The diversified program was organized into the Division of Research with the establishment of the Atomic Energy Commission in 1946 and was later renamed Basic Energy Sciences as it continued to grow through legislation included in the Atomic Energy Act of 1954, the Energy Reorganization Act of 1974, the Department of Energy Organization Act of 1977, and the Energy Policy Act of 1992.

Today, the mission of the BES program – a multipurpose, scientific research effort – is to foster and support fundamental research in focused areas of the natural sciences in order to expand the scientific foundations for new and improved energy technologies and for understanding and mitigating the environmental impacts of energy use. BES delivers the knowledge needed to support the President's National Energy Plan for improving the quality of life for all Americans. In addition, BES works cooperatively with other agencies and the programs of the National Nuclear Security Administration to discover knowledge and develop tools to strengthen national security and combat terrorism. As part of its mission, the BES program plans, constructs, and operates major scientific user facilities to serve researchers at universities, national laboratories, and industrial laboratories.

Strategic Objectives

SC4: Provide leading scientific research programs in materials sciences and engineering, chemical sciences, biosciences, and geosciences that underpin DOE missions and spur major advances in national security, environmental quality, and the production of safe, secure, efficient, and environmentally responsible systems of energy supply; as part of these programs, by 2010, establish a suite of Nanoscale Science Research Centers and a robust nanoscience research program, allowing the atom-by-atom design of revolutionary new materials for DOE mission applications, and restoring U.S. preeminence in neutron scattering research and facilities.

SC7: Provide major advanced scientific user facilities where scientific excellence is validated by external review; average operational downtime does not exceed 10% of schedule; construction and upgrades are within 10% of schedule and budget; and facility technology research and development programs meet their goals.

Progress toward accomplishing these Strategic Objectives will be measured by Program Strategic Performance Goals, Indicators, and Annual Targets, as follows:

Program Strategic Performance Goals

SC4-1: Build leading research programs in the scientific disciplines encompassed by the BES mission areas and provide world-class, peer-reviewed research results cognizant of DOE needs as well as the needs of the broad scientific community (Materials Sciences and Engineering Subprogram; Chemical Sciences, Geosciences, and Energy Biosciences Subprogram).

Performance Indicator

Validation of results by merit review with external peer evaluation.

Performance Standards

As discussed in Office of Science Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
BES used expert advisory committees and rigorous peer review committees to ascertain that the research performed by investigators in universities and DOE laboratories was focused and outstanding. An additional indicator of the success of our scientific research was the recognition through the awards received by our researchers and by the broader scientific community. (SC4-1) [Met Goal]	Competitively select and peer review at least 80 percent of all new research projects, and evaluate approximately 30 percent of ongoing projects using guidelines defined in 10 CFR 605 for the university projects and similar guidelines established by BES for the laboratory projects. (SC4-1)	Competitively select and peer review at least 80 percent of all new research projects, and evaluate approximately 30 percent of ongoing projects using guidelines defined in 10 CFR 605 for the university projects and similar guidelines established by BES for the laboratory projects. (SC4-1)
	As part of the continuing, high-level review of the management processes and the quality, the relevance, and the national and international leadership of BES programs, review the chemical sciences activities using a BESAC-chartered Committee of Visitors. In addition, evaluate the following ongoing efforts using BESAC- and BES-sponsored workshops with the goal of directing the activities toward international leadership and relevance to emerging technologies: superconductivity. Publish results and continue to structure BES programs per results. (SC4-1)	As part of the continuing, high-level review of the management processes and the quality, the relevance, and the national and international leadership of BES programs, review the materials sciences and engineering activities using a BESAC-chartered Committee of Visitors. In addition, evaluate the following ongoing efforts using BESAC- and BES-sponsored workshops with the goal of directing the activities toward international leadership and relevance to emerging technologies: photovoltaics, radiation effects, materials synthesis and processing, and catalysis. Publish results and continue to structure BES programs per results. (SC4-1)

SC4-2: Enable U.S. leadership in nanoscale science, allowing the atom-by-atom design of materials and integrated systems of nanostructured components having new and improved properties for applications as diverse as high-efficiency solar cells and better catalysts for the production of fuels (Materials Sciences and Engineering subprogram; Chemical Sciences, Geosciences, and Energy Biosciences subprogram).

Performance Indicator

Validation of results by merit review with external peer evaluation.

Performance Standards

As discussed in Office of Science Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Initiated 76 grants to universities (from 417 grant applications) and 12 projects at DOE laboratories (from 46 Field Work Proposals) in selected areas of nanoscale science, engineering, and technology. (SC4-2) [Met Goal]	Begin engineering and design of three Nanoscale Science Research Centers. (SC4-2)	Begin construction of one Nanoscale Science Research Center meeting the cost and timetables within 10 percent of the baselines given in the construction project data sheets, project number 03-R-312. Conduct engineering and design activities to establish construction baselines on the two other Nanoscale Science Research Centers. (SC4-2)
	Initiate approximately 40 grants to universities and 6 projects at DOE laboratories in selected areas of nanoscale science, engineering, and technology. (SC4-2)	Establish the instrument suites and identify fabrication capabilities for the new Nanoscale Science Research Centers based upon user community input at national workshops held in late FY 2001 and FY 2002. (SC4-2)

SC4-3: Develop advanced research instruments for x-ray diffraction, scattering, and imaging to provide diverse communities of researchers with the tools necessary for exploration and discovery in materials sciences and engineering, chemistry, earth and geosciences, and biology (Materials Sciences and Engineering subprogram; Chemical Sciences, Geosciences, and Energy Biosciences subprogram).

Performance Indicator

Validation of results by merit review with external peer evaluation.

Performance Standards

As discussed in Office of Science Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
		Select and begin upgrade/fabrication of at least two instruments at the BES synchrotron light sources, based on peer review of submitted proposals, to keep the facilities at the forefront of science. Because the lifetime of an instrument is about 7-10 years, this addresses the need to renew instruments on a regular basis. (SC4-3)
		Establish collaborative, national R&D programs for common needs at the BES synchrotron light sources, e.g., for detectors and other components. (SC4-3)

SC7-4A: Manage BES facility operations and construction to the highest standards of overall performance using merit evaluation with independent peer review. (Materials Sciences and Engineering subprogram; Chemical Sciences, Geosciences, and Energy Biosciences subprogram).

Performance Indicator

Validation of results by merit review with external peer evaluation.

Performance Standards

As discussed in Office of Science Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
BES scientific user facilities were maintained and operated so that the unscheduled downtime on average is less than 10 percent of the total scheduled operating time. The cost and schedule milestones for upgrades and construction of scientific user facilities, including the construction of the Spallation Neutron Source were met. [Met Goal]	Maintain and operate the BES scientific user facilities so the unscheduled downtime on average is less than 10 percent of the total scheduled operating time. Maintain the cost and schedule milestones within 10 percent for upgrades and construction of scientific user facilities. (SC7-4A)	Maintain and operate the BES scientific user facilities so the unscheduled downtime on average is less than 10 percent of the total scheduled operating time. Maintain the cost and schedule milestones within 10 percent for upgrades and construction of scientific user facilities. (SC7-4A)

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
	Continue upgrades on the major components of the SPEAR 3 storage ring at the Stanford Synchrotron Radiation Laboratory (SSRL), maintaining cost and schedule within 10 percent of baselines. At the end of FY 2002, the upgrade of SPEAR 3 will be 70 percent complete. (SC7-4A)	Complete the upgrade of the SPEAR 3 storage ring at the Stanford Synchrotron Radiation Laboratory (SSRL), maintaining cost and schedule within 10 percent of baselines. (SC7-4A)

SC7-4B: Restore U.S. preeminence in neutron scattering research, instrumentation, and facilities to provide researchers with the tools necessary for the exploration and discovery of advanced materials (Materials Sciences and Engineering subprogram; Chemical Sciences, Geosciences, and Energy Biosciences subprogram).

Performance Indicator

Validation of results by merit review with external peer evaluation.

Performance Standards

As discussed in Office of Science Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
	Continue construction of the Spallation Neutron Source (SNS), meeting the cost and timetables within 10 percent of the baselines in the construction project data sheet, project number 99-E-334. At the end of FY 2002, construction of the SNS will be 47 percent complete. (SC7-4B)	Continue construction of the Spallation Neutron Source (SNS) meeting the cost and timetables within 10 percent of the baselines given in the construction project data sheet, project number 99-E-334. At the end of FY 2003, construction of the SNS will be 61 percent complete. (SC7-4B)
	Select and begin fabrication of one additional instrument for the SNS. (SC7-4B)	Select and begin fabrication of one additional instrument for the SNS. Select and begin upgrade/fabrication of one instrument each at the High Flux Isotope Reactor and the Manuel Lujan, Jr. Neutron Scattering Center. Commitment at the Lujan Center is conditional upon LANSCE demonstrating reliable operations as determined by a BESAC review conducted in FY 2003. (SC7-4B)

Significant Accomplishments and Program Shifts

The BES program continues as one of the Nation's largest sponsors of fundamental research in the natural sciences and is uniquely responsible for supporting research impacting energy resources, production, conversion, efficiency, and the mitigation of the adverse impacts of energy production and use. In FY 2001, the program funded research in more than 150 academic institutions located in 48 states and in 13 Department of Energy (DOE) laboratories located in 9 states. BES supports a large extramural research program, with approximately 40% of the program's research activities sited at academic institutions.

The *National Energy Policy* noted that the U.S. economy grew by 126% since 1973, but energy use increased by only 30%. Approximately one-half to two-thirds of the savings resulted from technological improvements in products and services that allow consumers to enjoy more energy services without commensurate increases in energy demand. At the heart of these improvements is fundamental research. During this 30-year period, the basic research supported by the BES program has touched virtually every aspect of energy resources, production, conversion, efficiency, and waste mitigation. The basic knowledge derived from fundamental research has resulted in a vast array of advances, including • high-energy and high-power lithium and lithium ion batteries and thin-film rechargeable microbatteries; • thermoacoustic refrigeration devices that cool without moving parts and without the use of freons; • compound semiconductors, leading to the world's highest efficiency photovoltaic solar cells; • catalysts for the production of new polymers (annually, a multibillion dollar industry) and for a host of other products and energy-efficient processes; • high-strength, lightweight magnets for sensors and for small motors used in power steering and other vehicle functions; • strong, ductile alloys for use in high-temperature applications; • toughened (i.e., nonbrittle) ceramics for use in hammers, high-speed cutting tools, engine turbines, and other applications requiring lightweight, high-temperature materials; • new steels, improved aluminum alloys, magnet materials, and other alloys; • polymer materials for rechargeable batteries, car bumpers, food wrappings, flat-panel displays, wear-resistant plastic parts, and polymer-coated particles in lubricating oils; • new commercial processes for ethanol production, pulp and paper manufacturing, and *in planta* production of oils built on foundations laid by the Energy Biosciences activities; • processes for extraction of radioactive and hazardous metal ions from solutions for nuclear fuel purification/reprocessing and for cleanup of radioactive wastes; • the atomic-level understanding of combustion processes as a result of the creation of the Combustion Research Facility, where basic, applied, and industrial research are collocated; and • a host of new instruments, e.g. instruments based on high-temperature superconductors — "superconducting quantum interference devices" or SQUIDs for short — that can sense the minute magnetic fields that emanate from the human brain and heart. These advances came by exploiting the results of basic research that sought answers to fundamental questions.

The BES program also supports world-class scientific user facilities, providing outstanding capabilities for imaging and characterizing materials of all kinds from metals, alloys, and ceramics to fragile biological specimens and crystals. The BES synchrotron radiation light sources, the neutron scattering facilities, and the electron beam characterization centers represent the largest and best collection of such facilities supported by a single organization in the world. Annually, 8,000 researchers from universities, national laboratories, and industrial laboratories perform experiments at these facilities. Spurred by results of past investments and by innovations in accelerator concepts, the BES program continues its pioneering role in the development of new generations of scientific research instruments and facilities.

FY 2001 Honors and Awards

Each year, 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 are six Nobel Prizes awarded to BES principal investigators since the mid-1980s. Selected major prizes and awards for FY 2001 include:

From Acta Metallurgica, Inc. -- Acta Metallurgica Gold Medal

From ASM International -- the 2001 ASM International Gold Medal

From R&D Magazine -- R&D 100 Award for the invention of the MOLYCAST Furnace, an environmentally friendly system of new energy efficient heating elements.

From the Alexander von Humboldt Foundation of Germany -- the Humboldt Research Award

From the American Association of Engineering Societies -- the John Fritz Medal

From the American Chemical Society -- the Award in Chemistry of Materials; the Award in Colloid or Surface Chemistry; the Arthur C. Cope Scholar Award; the Arthur W. Adamson Award for Distinguished Service in the Advancement of Surface Chemistry; the Nobel Laureate Signature Award for Graduate Education in Chemistry; the Award for Creative Research in Homogeneous or Hetergeneous Catalysis

*From the American Institute of Chemical Enginee*rs -- the William H. Walker Award

From the American Physical Society -- the Irving Langmuir Prize in Chemical Physics; the Herbert P. Broida Prize

From the American Vacuum Society -- the Medard W. Welch Award; the John A. Thornton Award

From the American Welding Society -- four recipients of the William Spraragen Award

From the Computing Research Association -- an Honorable Mention in the Computing Research Association's Outstanding Undergraduate Award

From the Electrochemical Society -- the David C. Graham Award in Physical Electrochemistry

From the German Society for Physical Chemistry -- the Jost Memorial Award

From the Iron and Steel Society -- the Geoffrey Belton Award

From the Japan Fine Ceramics Association -- the 2001 International Prize

From the Materials Research Society -- the Materials Research Society Medal for 2001

From the Metals, Minerals, and Materials Society -- the Robert Lansing Hardy Award

From the Samsung Foundation -- the Ho-Am Prize for Science

Twelve principal investigators were elected to the National Academy of Sciences, and six were elected to the National Academy of Engineering. Fifteen principal investigators were advanced to fellowship in the American Physical Society; seven in the American Academy of Arts and Sciences; one in the American Ceramics Society; four in the Minerals, Metals, and Materials Society; and two in the John Simon Guggenheim Memorial Foundation.

Selected FY 2001 Science Accomplishments

Materials Sciences and Engineering

- *Micro-size Light Emitters for Solid State Lighting Applications.* Energy savings of tens of billions of dollars per year could be achieved by replacement of household 100-watt light bulbs by white light emitting diodes (LED) made by mixing LEDs emitting primary colors. However, improved LED efficiency is necessary before such replacement becomes feasible. New research has shown that interconnecting hundreds of micro-size LEDs to replace larger conventional LEDs can boost the overall emission efficiency by as much as 60 percent.
- *A New Method for Obtaining Crystal Structures Without Large Crystals.* High-resolution x-ray diffraction using polycrystalline samples ("powders") rather than traditional single-crystal samples has advanced to the point where the structures of complex materials including oxides, zeolites, and small organic structures can be solved. Advantages of powder diffraction are that it is not affected by crystal fracture and polycrystalline samples can be formed over a much wider range of conditions than large single crystals. Recently, powder diffraction was demonstrated for large molecules, such as proteins, that were considered far too complex for powder diffraction experiments. In addition to the many important applications to materials sciences, this technique will also be useful in chemistry and biosciences.
- *NMR and MRI Outside the Magnet.* NMR (nuclear magnetic resonance) imaging and MRI (magnetic resonance imaging) have required large high-field magnets that impose extremely uniform magnetic fields upon the sample. In many circumstances, however, it is impractical or undesirable to place or rotate objects and subjects within the bore of such a large magnet. A new approach for the recovery of highly resolved NMR spectra and MRI images of samples in grossly non-uniform magnetic fields was recently demonstrated. The approach will be useful for the enhanced study of fluids contained in porous materials, such as deep underground oil-well logging studies, and is expected to have dramatic research applications in chemistry, materials sciences, and biomedicine.
- *Terabit Arrays (One trillion bits per square inch).* A 300-fold increase in magnetic storage density has been achieved using a patented technique of self-assembly of block copolymers under the influence of a small voltage. The new technique is simple, robust, and extremely versatile. The key to this discovery lay in directing the orientation of nanoscopic, cylindrical domains in thin films of block copolymers. By coupling this with routine lithographic processes, large area arrays of nanopores can be easily produced. Electrochemical deposition of metals, such as cobalt and iron, produces nanowires that exhibit excellent magnetic properties, key to ultrahigh density magnetic storage. The nanowires are also being used as field emission devices for displays.
- *Observations of Atomic Imperfections.* A new electron beam technique has been developed that has measured atomic displacements to a record accuracy of one-hundredth of the diameter of an atom. Such small imperfections in atomic packing often determine the properties and behavior of materials, particularly in nano-structured devices. This capability has been made possible by a new technique that couples electron diffraction with imaging technology. The result is a greatly enhanced capability to map imperfections and their resulting strain fields in materials ranging from superconductors to multi-layer semiconductor devices.

- *Semiconductor Nanocrystals as "Artificial Leaves."* Recent experiments demonstrated that carbon dioxide could be removed from the atmosphere with semiconductor nanocrystals. These "artificial leaves" could potentially convert carbon dioxide into useful organic molecules with major environmental benefits. However, to be practical, the efficiency must be substantially improved. New theoretical studies have unraveled the detailed mechanisms involved and identified the key factors limiting efficiency. Based on this new understanding, alternative means for improving efficiency were suggested that could lead to effective implementation of artificial leaves to alleviate global warming and the depletion of fossil fuels.

- *"Magic" Values for Nanofilm Thickness.* A key issue for nanotechnology is the structural stability of thin films and the devices made from nanostructures. It was recently demonstrated that nanofilms are significantly more stable at a few specific values of film thickness. The origin of this effect arises from the confinement of electrons within the film leading to electronic states with discrete energy values, much as atomic electrons are bound to the nucleus at discreet energy levels. Calculations demonstrated that increased stability occurred when the number of electrons present in the film completely filled the set of available states, just as filled electronic shells make the mobile gases very stable.

- *Materials Resistant to Damage from Nuclear Waste.* The ability to predict the composition and structure of materials that are resistant to radiation damage, such as in nuclear waste storage, has been formulated on a firm scientific basis. Current nuclear storage materials cannot resist radiation damage for the required thousands of years because radioactive emissions in a storage material jostle atoms out of their carefully ordered arrangements. These materials become unstable and eventually leach into the environment. Computer simulations and experiments revealed that a special class of complex ceramic oxides called fluorites is able to resist this fate. The fundamental principle is rather simple: the configurations of atomic arrangements in these oxides are relatively disordered to begin with allowing them to tolerate displaced atoms caused by radiation.

- *Brilliant X-Rays Shine Light on Welds.* Using high-brightness synchrotron radiation, the details of microstructural changes of welds were mapped and studied for the first time. This advanced capability shows how the welding process alters the structure and changes the properties of metals. Its application is virtually unlimited, since it can investigate dynamic changes in crystal structure near the melting point of any metal. Knowledge gained from this award winning work on titanium and stainless steels is being used to advance and refine theories and numerical models of welding fundamentals. Dramatic savings to the U. S. economy would result from better quality, more reliable welds.

- *Micro Lens for Nano Research.* A silicon lens that is 1/10 the diameter of a human hair has been fabricated and used to image microscopic structures with an efficiency 1,000 times better than existing probes. The combination of high optical efficiency and improved spatial resolution over a broad range of wavelengths has enabled measurement of infrared light absorption in single biological cells. This spectroscopic technique can provide important information on cell chemical composition, structure, and biological activity.

- *Nanofluids.* Nanofluids (tiny, solid nanoparticles suspended in fluid) have been created that conduct heat ten times faster than thought possible, surpassing the fundamental limits of current heat conduction models for solid/liquid suspensions. These nanofluids are a new, innovative class of heat transfer fluids and represent a rapidly emerging field where nanoscale science and thermal engineering meet. This research could lead to a major breakthrough in making new composite (solid and liquid) materials with improved thermal properties for numerous engineering and medical applications to achieve greater energy efficiency, smaller size and lighter weight, lower operating costs, and a cleaner environment.

Chemical Sciences, Geosciences, and Energy Biosciences

- *Capturing Molecules in Motion with Synchrotron X-Ray Pulses.* Photochemical conversion of solar energy depends on light-driven chemical reactions. Absorption of light ultimately leads to atomic rearrangements necessary to produce photochemical products. The intermediate molecular configurations created by absorption of light are short-lived and their structures are largely unknown. In novel experiments at the Advanced Photon Source, molecular structures of laser-generated reaction intermediates in solutions, having lifetimes as short as 28 billionth of a second, have been obtained. Future experiments are planned that will allow for capture of intermediate structures on even shorter time scales. These studies are providing the fundamental knowledge needed to develop artificial photoconversion devices.
- *Early Precursor Identified in Water Radiolysis.* Radiolytic decomposition of water produces hydrogen gas, which is flammable and potentially explosive. This is of concern in maintenance of water-moderated nuclear reactors, long-term storage of transuranic fissile materials containing adsorbed water, and management of high-level mixed-waste storage tanks. In recent studies on the effects of ionizing radiation on condensed media, a common precursor to essentially all hydrogen from irradiated water has been discovered. This precursor is a solvated electron. External intervention and capture of this precursor can prevent the generation of hydrogen gas from water. The reactivity of the precursor with a large number of scavengers has previously been determined in pulse radiolysis experiments, thus a priori predictions can be made on the efficiency of the intervention and prevention of gas generation.
- *The World's Smallest Laser.* A team of materials scientists and chemists has built the world's smallest laser - a nanowire nanolaser 1,000 times thinner than a human hair. The device, one of the first to arise from the field of nanotechnology, can be tuned from blue to deep ultraviolet wavelengths. Zinc oxide wires only 20 to 150 nanometers in diameter and 10,000 nanometers long were grown, each wire a single nanolaser. Discovering how to excite the nanowires with an external energy source was critical to the success of the project. Ultimately, the goal is to integrate these nanolasers into electronic circuits for use in "lab-on-a-chip" devices that could contain small laser-analysis kits or as a solid-state, ultraviolet laser to allow an increase in the amount of data that can be stored on high-density optical disks.
- *Polymerization to Make Plastics.* The discovery of metallocene catalysts caused major advances in polymer production (e.g., polyethylene, polypropylene), the most widespread of synthetic materials. The ability to control the orientation of each link of a polymer chain allows control of crystallinity, density, softening point, and other important properties. A recent improvement in these catalysts is the synthesis of bimetallic complexes in which two catalytic centers and two cocatalytic centers are held in close proximity in solution or adsorbed on surfaces. By altering the nature of the centers, it is possible to control rate of reactivity, the degree of chain branching, and plastic rigidity.
- *First Ever Chemistry with Hassium, Element 108.* Element 108 - hassium - was discovered in 1984. It does not exist in nature but must be created one atom at a time by fusing lighter nuclei. Recently, the first experiments to examine its chemical properties were performed by an international team (German, Swiss, Russian, Chinese and American scientists) at the Gesellschaft für Schwerionenforschung (GSI) in Darmstadt, Germany using novel techniques developed at the Lawrence Berkeley National Laboratory. Energetic magnesium projectiles bombarded targets of

curium, a rare artificial isotope produced and processed at Oak Ridge National Laboratory. The hassium atoms formed by impacts between beam and target reacted with oxygen to form hassium oxide molecules enabling the study of the properties of this new chemical compound. The chemistry of man-made and heavy elements, particularly chemistry impacting environmental insults, is of major interest, and these experiments are a first step for this element.

- *Improved Materials for Fuel Cells.* Major impediments for the commercialization of fuel cells include the inability to use hydrogen fuel containing traces of carbon monoxide and the necessity of using large amounts of expensive platinum catalysts. A novel ruthenium/platinum catalyst has been produced through a new preparation method involving spontaneous deposition of platinum on metallic ruthenium nanoparticles. The resulting catalyst has a higher carbon monoxide tolerance than commercial catalysts and uses smaller amounts of platinum.
- *Platinum Encrusted Diamond Films.* Research on new catalytic electrodes, e.g., for fuel cells, has shown that synthetic diamond thin films are excellent supports for catalysts because of their corrosion resistance. The challenge to produce an electrode is to incorporate nanometer sized platinum and platinum/ruthenium catalyst particles into the surface structure of the diamond film. Recently, the ability to incorporate 10 to 500 nanometer diameter particles into the bulk structure of the films has been demonstrated. These new surface modified systems may result in significantly improved catalytic activity and stability, and could have even broader applications in chemical synthesis, toxic waste remediation, and chemical and biomedical sensors.
- *Complex Flow in the Subsurface.* Recovery of subsurface fluids, whether oil and gas or contaminants, requires understanding the way fluids flow within porous and fractured rocks and soil. This is particularly complicated when there are multiple fluids (oil-methane-water; water-carbon dioxide). New experiments combined with theory and computational modeling have tracked the simultaneous flow of two fluids in fractured and porous media. Flow paths of both fluids are significantly longer than under single fluid conditions and transport is very sensitive to differences in fluid structure.
- *Complete Plant Genome of the First Model Plant.* The first complete sequencing of a plant genome was completed by an international consortium of researchers from Europe, Japan and the U.S. The DOE was one of the supporters of the U.S. effort. The sequencing of the genome of Arabidopsis will provide the information needed to increase food production in an energy-efficient and environmentally friendly manner, provide increased wood and fiber production, and increase the use of plant materials for energy and the production of petroleum-replacing chemicals.

Selected FY 2001 Facility Accomplishments

The four synchrotron radiation light sources and three BES neutron scattering facilities served 6,982 users in FY 2001 by delivering a total of 26,476 operating hours to 204 beam lines at an average of 96.1% reliability (delivered hours/scheduled hours)[a]. The High Flux Isotope Reactor at Oak Ridge National Laboratory did not operate in FY 2001 due to the installation of upgrades. Statistics for individual facilities are provided below. In one instance, less time was needed for maintenance activities than was scheduled, so more time was delivered to users than planned.

The maximum number of total operating hours for these 7 facilities is estimated to be about 37,100 hours. Most of the BES facilities already operate close to the maximum number of hours possible for their facility. The next priority is to support and maintain beamlines and instruments at the state-of-the art. For the synchrotron radiation light sources and the neutron scattering facilities, the number of beamlines and instruments would need to be increased in order to achieve the full capacity of each of the facilities. Capacity at the light sources could increase by nearly a factor of two if all beamlines were fully instrumented. Capacity at the neutron sources could also increase substantially by upgrading existing instruments and fabricating new ones. These needs are addressed in the current request.

- **The Advanced Light Source (ALS)** served 1,163 users in FY 2001 by delivering 5,261 operating hours to 37 beam lines at 96.2% reliability (delivered hours/scheduled hours). The ALS is supported by the Materials Sciences and Engineering subprogram.

  - *A new beamline for x-ray microscopy of polymers.* Owing to its elemental and chemical specificity, x-ray microscopy is a superior tool for the study of multicomponent polymers. A scanning x-ray microscope that is specifically optimized to the demands of polymer research is being commissioned.

  - *Ambient-pressure photoemission spectroscopy.* The real world of chemistry, biology, and environmental science is a world that is frequently wet, hot, and under atmospheric or higher pressures, whereas experimental measurements are often best done under vacuum with cold samples. One step toward bridging the gap is the development of a new experimental chamber for *in-situ* investigation of samples under ambient conditions.

  - *Interferometer controls scanning x-ray microscope.* In scanning microscopy, it is essential to locate and control the position of the probe over the sample. A control system developed for a scanning x-ray microscope is able to position the x-ray beam with nanometer accuracy, so that features in the sample can be studied at the finest spatial resolution of the instrument.

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[a] BES defines "users" as researchers who conduct experiments at a facility (e.g., received a badge) or receive primary services from a facility. An individual is counted as one user per year regardless of how often he or she uses a given facility in a year. “Operating hours” are the total number of hours the facility delivers beam time to its users during the Fiscal Year. Facility operating hours are the total number of hours in the year (e.g., 365 days times 24 hour/day = 8,760 hours) minus time for machine research, operator training, accelerator physics, and shutdowns (due to maintenance, lack of budget, faults, safety issues, holidays, etc.).

- ► *Superbend beamlines developed.* To broaden the spectral range of the Advanced Light Source to cover shorter wavelengths, superconducting bend magnets were designed. The first two beamlines will be implemented sequentially over the next year to serve protein crystallographers and to provide much needed harder x-ray sources for ALS diffraction studies.

- **The Advanced Photon Source (APS)** served 1,989 users in FY 2001 by delivering 4,788 operating hours to 37 beam lines at 95.8% reliability (delivered hours/scheduled hours). The APS is supported by the Materials Sciences and Engineering subprogram.

  - ► *Storage ring "top-up operation" becomes routine.* After successful tests with 25% of the scheduled user-beam time dedicated to top-up operation, the APS is scheduling the majority of future operations for top-up mode. During top-up operation, injecting a pulse of electrons once every two minutes holds the stored current constant to 0.2 percent. This operating mode delivers a constant heat load on x-ray optics and various accelerator components, thus improving the x-ray beam stability. It also allows flexibility in operating modes, which are traditionally limited by the short lifetime of the stored beam. Top-up operation has significantly enhanced the research capabilities of the APS.

  - ► *Two undulators on a single straight section deliver two independent x-ray beams to users.* For the first time, a novel concept of spatially separating the beams from two insertion devices placed on single straight section was realized. This was accomplished by placing the undulator axes at a small angle with respect to each other. Successful implementation of this concept enabled 100% efficient utilization of the delivered beam.

  - ► *Low-emittance lattice developed.* Machine studies have successfully established operating conditions for the APS storage ring with the horizontal emittance reduced by approximately a factor of two. This reduces the horizontal source size and divergence of the x-ray beam and results in at least a factor of two improvement in the overall brilliance. Initial user results are encouraging and routine operation with this mode is scheduled for the near future.

- **The National Synchrotron Light Source (NSLS)** served 2,523 users in FY 2001 by delivering 5,556 operating hours to 86 beam lines at 100.0% reliability (delivered hours/scheduled hours). The NSLS is supported by the Materials Sciences and Engineering subprogram.

  - ► *Polarization modulation spectroscopy for magnetism research.* A new high-resolution soft x-ray beamline and a phase sensitive detection system were completed to take advantage of the fast switching capability of the Elliptically Polarized Wiggler. The new system provides high sensitivity and enables magnetic field dependent studies.

  - ► *Focusing of high energy x-rays with asymmetric Laue crystals.* Theoretical prediction and experimental verification of a new concept for focusing of high energy x-rays was demonstrated. This new design results in a more than 100 fold increase in the photon flux delivered to the sample. A new monochromator based on this design was constructed and implemented at the superconducting wiggler beamline for high pressure and materials research.

  - ► *High magnetic field, far-infrared spectroscopy beamline commissioned.* A new high magnetic field, far-infrared beamline was commissioned with a far-infrared spectrometer and 16 Tesla superconducting magnet. Combining this with a high-field magnet system opens up new opportunities for measuring electron spin resonance (ESR), cyclotron resonance, and other magneto-optic effects in solids.

- *X-ray optics for microbeam diffraction, elemental mapping, and high pressure research developed.* A new system for micro-focusing of x-rays was implemented, achieving a focus of 3 microns (vertical) by 9 microns (horizontal). The system has been used in the study of bone diseases, materials under high pressure, and semiconductors.

- *High gain harmonic generation (HGHG) free electron laser (FEL) achieves saturation.* By frequency multiplying and amplifying a seed laser signal, an HGHG FEL imposes the properties of the laser onto the FEL output beam. In a demonstration, light at long wavelength was frequently doubled. Full characterization of the FEL light and its harmonics agreed with theory and demonstrated the utility of an HGHG FEL for producing intense coherent light pulses.

- **The Stanford Synchrotron Radiation Laboratory (SSRL)** served 907 users in FY 2001 by delivering 4,539 operating hours to 25 beam lines at 94.9% reliability (delivered hours/scheduled hours). The SSRL is supported by Materials Sciences and Engineering subprogram.

  - *Stanford-Berkeley synchrotron radiation summer school.* The first Stanford-Berkeley summer school on synchrotron radiation and its applications was held with 36 students from a diverse range of scientific fields. The goal was to introduce young scientists to the fundamental properties of synchrotron radiation and the understanding and use of several techniques, including spectroscopy, scattering, and microscopy.

  - *New actinide facility commissioned.* Synchrotron-based measurements are a crucial part of chemical and materials research programs involving radionuclides and radiologic materials. In order not to limit the scope of experiments that can be performed, a radiologic sample analysis facility has been integrated into a modern synchrotron beamline. This combination insures safe handling of actinide and other radiology materials and also provides state-of-the-art measurement capabilities that have proven extremely useful in remediation efforts.

  - *Materials science small angle x-ray scattering beamline facility completed.* The materials science small and wide-angle x-ray scattering station is now in full user operation. The integrated beamline and experimental equipment facility allows for studies of weakly scattering systems, such as dilute polymer solutions.

  - *Microfocus optics system for X-ray micro-spectroscopy.* An experimental apparatus employing tapered metal capillary optics for conducting X-ray micro-spectroscopy is now in operation. This capability allows X-ray micro-spectroscopy experiments in the materials, biological, and environmental sciences.

  - *Successful 3 GeV injector test.* The SPEAR injector was successfully run at 3 GeV, proving that it is ready to provide at-energy injection for SPEAR3. The 3 GeV test came toward the end of the two-year Injector Upgrade Accelerator Improvement Project, in which power supplies, magnets, and diagnostics were upgraded to insure reliable 3 GeV operation. At-energy injection will improve SPEAR3 performance by providing better fill-to-fill orbit reproducibility and thermal stability.

- ► *RF waveguide dampers improve beam stability and lifetime.* RF waveguide dampers were installed in the two radio frequency (RF) waveguides in the SPEAR storage ring to eliminate high frequency oscillations excited by the electron beam in the RF cavity/waveguide system. The dampers not only eliminated the instabilities but they allowed the use of operations parameters that gave a 20% improvement in the electron beam lifetime.

- **The Intense Pulsed Neutron Source (IPNS)** served 240 users in FY 2001 by delivering 3,968 operating hours to 13 beam lines at 102.6% reliability (delivered hours/scheduled hours). The IPNS is supported by the Materials Sciences and Engineering subprogram.

  - ► *IPNS hosts the national neutron and x-ray scattering school.* In August 2001, Argonne National Laboratory again hosted the two-week National School on Neutron and X-Ray Scattering. The school continues to attract outstanding graduate students and post-doctoral appointees with 179 applications for the 60 available positions.

  - ► *Upgrade of IPNS instruments.* The High Resolution Medium Energy Chopper Spectrometer (HRMECS) instrument was completely upgraded and a chopper was added to the General Purpose Powder Diffractometer (GPPD). The HRMECS upgrade included the complete overhaul of data collection/control software and hardware, addition of position-sensitive detectors at low scattering angles and improved neutron choppers. The T0 chopper on GPPD blocks high energy neutron from entering the diffractometer.

  - ► *Auto-anneal capabilities added to moderator system.* Regular annealing required for IPNS's unique ultra-cold moderator has been accomplished by installing a system that automatically anneals the solid methane moderator every three days. This automation allows for reduced manpower and improved operation of the IPNS target moderator assembly.

- **The Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center** LANSCE served 122 users in FY 2001 by delivering 2,364 operating hours to 6 beam lines at 82.0% reliability (delivered hours/scheduled hours). The Lujan Center is supported by the Materials Sciences and Engineering subprogram.

  - ► *HIPPO diffractometer commissioned.* Following three years of design and construction, the recently completed HIPPO (High Pressure, Preferred Orientation) diffractometer took its first neutron-beam-related diffraction pattern on a sample of nickel on July 7, 2001. The scientific thrust of this new state-of-the-art spectrometer is the investigation of dynamic processes in heterogeneous bulk materials in a variety of environments.

  - ► *SMARTS will provide new capabilities in materials research.* SMARTS, a third generation neutron diffractometer for the study of polycrystalline materials, received its load frame and furnace, which were successfully tested onsite during 2001. SMARTS is scheduled to receive first beam in August 2001, followed by commissioning through the remainder of the year.

  - ► *BES partners on new institutional instruments.* Three institutionally funded instruments, ASTERIX, PHAROS, and IN500 were supported in part under the auspices of BES. ASTERIX produces a highly polarized intense beam of cold neutrons that has a very large cross section and covers a wide wavelength range while minimizing the fraction of the neutron beam that is not used. PHAROS, a high-resolution chopper spectrometer, is designed for low-angle studies.

IN500 is a cold neutron time-of-flight spectrometer, which will offer all the advantageous capabilities of reactor-based instruments.

- *Instrument performance improves with use of new chopper technology.* All of the Lujan Center's new instruments and some of the existing instruments have enjoyed dramatic improvements in chopper technology in FY 2001. These performance improvements in two technical areas, timing reference generators and chopper controls, now enable the accelerator and all neutron choppers to run as slaves of the master timing generator. This success in chopper technology has drawn the attention of several other spallation neutron facilities and has redefined the timing specifications for the Spallation Neutron Source.

- *Upgrades to small-angle scattering instrument.* A new frame-overlap chopper was procured and installed, which enables the small-angle scattering instrument, LQD, to make full use of the higher flux it enjoys from the hydrogen moderator installed over the last two years. Recent additions to LQD also include a gravity-focusing device, which compensates for gravitational drop, especially for slow neutrons.

- *Upgrades to SPEAR improve instrument performance.* SPEAR (Surface Profile Analysis Reflectometer) is used for determining chemical density profiles at solid/solid, solid/liquid, solid/gas, and liquid/gas interfaces. Upgrades to SPEAR during 2001 included the installation of shutter hardware to reduce closure time, and additional automation of flight-path components. For better performance, an evacuated flight path, and two digital chopper controllers were added. In addition, a new collimation system, together with improved software, allowed for the first real-time reflectivity measurements. These upgrades were made to make the instrument user-friendlier.

- **The High Flux Isotope Reactor (HFIR)** served 38 users in FY 2001 by delivering 8 operating hours for materials irradiation and institutes that utilize the transplutonium program and medical isotopes. The reactor was shut down at 8:00 a.m. on October 1, 2000, for the scheduled replacement of the beryllium reflector and installation of upgrades and remained shutdown for the remainder of the year. The HFIR is supported by the Materials Sciences and Engineering subprogram.

  - *Installation of new components enhances scientific capabilities at HFIR.* Many of HFIR’s internal components have been replaced with new, upgraded components that will significantly enhance its neutron scattering research capabilities without diminishing its isotope-production or material-testing capabilities. Replaced components include the beryllium reflector, its support structure, and three of the four neutron beam tubes. Beam intensity for some instruments is expected to be three times that of the original design.

  - *Cold Source Project progress.* The moderator vessel has been fabricated and has passed acceptance pressure tests at room and liquid-nitrogen temperatures.

  - *Spectrometers for cold neutron research.* The cold source to be installed at HFIR will provide long wavelength neutron beams that are unsurpassed worldwide. Instrumentation has been designed to make optimum use of the cold neutron beams. Instruments include small angle spectrometers for measurements on large-scale structures, reflectometers for the study of surface phenomena, and triple-axis spectrometers for the determination of low-energy excitations.

- *Spectrometers for thermal neutron research.* The larger beam tubes and new mochromator drums installed at HFIR will permit considerable gains in intensity for the thermal neutron spectrometers, by as much as a factor of five.

- **The Combustion Research Facility (CRF)** is supported by the Chemical Sciences, Geosciences, and Energy Biosciences subprogram.

  - *New capabilities.* The CRF provides a primary interface for the integration of BES programs with those of DOE's Offices of Energy Efficiency and Renewable Energy and Fossil Energy related to combustion by collocating basic and applied research at one facility. Three laboratories were completed. The particle diagnostic laboratory can now generate flames with controllable fuel and oxidizer feeds to develop a fundamental understanding of small particle formation from combustion sources. A time-resolved fourier transform spectrometer for chemical kinetics and dynamics studies is now available in the kinetics and mechanisms laboratory. Related to applied research, the investigation of a novel engine combustion concept is being conducted in the new homogeneous-charge, compression-ignition engine laboratory.

Program Shifts

In FY 2003, the engineering activity of the formerly separate Engineering and Geosciences subprogram becomes part of the Materials Sciences and Engineering subprogram. The geosciences activity of the formerly separate Engineering and Geosciences subprogram and the Energy Biosciences subprogram become part of the Chemical Sciences, Geosciences, and Energy Biosciences subprogram. This directly aligns Basic Energy Sciences program management and organizational structures.

Materials Sciences and Engineering

- *Initiation of new activities in nanoscale science, engineering, and technology (NSET).* The FY 2001 NSET laboratory solicitation resulted in six awards including: Lawrence Berkeley National Laboratory in the areas of self assembly of organic/inorganic nanocomposite materials and the design, synthesis, characterization, and applications of functionalized nanotubes; Oak Ridge National Laboratory in the area of self-organized and artificially structured nanoscale materials, with emphasis on neutron scattering; Brookhaven National Laboratory in the area of electron microscopy applied to nanoscale structures; Los Alamos National Laboratory in the area of electronics from nanoscale crystals; and Sandia National Laboratories in the area of nanoelectronics and nanophotonics. The FY 2001 NSET university solicitation resulted in 35 grants.

- *Initiation of new activities in Robotics and Intelligent Machines (RIM).* The FY 2001 RIM university solicitation resulted in four grants for fundamental studies of automated sensing, perception, learning, and action.

Chemical Sciences, Geosciences, and Energy Biosciences

- *Initiation of new activities in nanoscale science, engineering, and technology (NSET).* The FY 2001 NSET laboratory solicitation resulted in six awards including: Argonne National Laboratory in the area of integrating the biomolecule - inorganic interface to build functional materials; Brookhaven National Laboratory in the areas of understanding the chemical reactivity of nanoparticle surfaces and research on electron and photon transfer through molecules connecting nanoparticles; National Renewable National Laboratory in the area of quantum dot communication through proteins and nanotubes; Oak Ridge National Laboratory in the area of research on templated synthesis and reactivity of nanoparticles for energy and environmentally demanding reactions; and Lawrence Berkeley National Laboratory in the area of designing nanoparticle surfaces for controlling reaction selectivity. The FY 2001 NSET university solicitation resulted in 41 grants.

- *Initiation of new research in computational chemistry as part of the Scientific Discovery through Advanced Computing (SciDAC) activities.* The FY 2001 SciDAC laboratory solicitation resulted in awards to Ames Laboratory in the area of advancing multi-reference methods in electronic structure theory; Pacific Northwest National Laboratory and Lawrence Berkeley National Laboratory in the area of advanced methods for electronic structure; Sandia National Laboratory in the area of computation of reacting flows; and Argonne National Laboratory and Sandia National Laboratory for advanced software for the calculation of thermochemistry, kinetics and dynamics. The FY 2001 SciDAC university solicitation for computational chemistry resulted in 10 grants.

Scientific Facilities Utilization

The BES program request includes $313,887,000 to maintain support of the scientific user facilities. Research communities that have benefited from these facilities include materials sciences, condensed matter physics, chemical sciences, earth and geosciences, environmental sciences, structural biology, superconductor technology, medical research, and industrial technology development. The level of operations will be equal to that in FY 2002. 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.

Nanoscale Science Research

In FY 2003, fundamental research to understand the properties of materials at the nanoscale will be increased in three areas: synthesis and processing of materials at the nanoscale; condensed matter physics; and catalysis. In the area of synthesis and processing (Materials Sciences and Engineering subprogram), new activities will develop a fundamental understanding of nanoscale processes involved in deformation and fracture, synthesis of ordered arrays of nanoparticles using patterning techniques, and synthesis of nanoparticles of uniform size and shape. In the area of condensed matter physics (Materials Sciences and Engineering subprogram), new activities will focus on understanding how properties change or can be improved at the nanoscale and how macromolecules reach their equilibrium configuration and self assemble into larger structures. In the area of catalysis (Chemical Sciences, Geosciences, and Energy Biosciences subprogram), new work will focus on fundamental research to understand the role nanoscale properties of materials play in altering and controlling catalytic transformations. In FY 2003, requests for applications in these research areas will be issued to DOE laboratories and to universities. The combination in a single coordinated research program of individual investigators at universities and interdisciplinary groups at the Department's laboratories is a proven excellent mechanism for incorporating advanced basic research, cutting-edge instrumentation, access to facilities, and the needs of energy technologies.

In addition to the increases for research in FY 2003, construction will begin on one Nanoscale Science Research Center (NSRC), and engineering and design will continue on two others. NSRCs are user facilities for the synthesis, processing, fabrication, and analysis of materials at the nanoscale. NSRCs were conceived in FY 1999 within the context of the NSTC Interagency Working Group on Nanoscale Science, Engineering, and Technology as part of the DOE contribution to the National Nanotechnology

Initiative. They involve conventional construction of a simple laboratory building, usually sited adjacent to or near an existing BES synchrotron or neutron scattering facility. Contained within NSRCs will be clean rooms; chemistry, physics, and biology laboratories for nanofabrication; and one-of-a-kind signature instruments and other instruments, e.g., nanowriters and various research-grade probe microscopies, not generally available outside of major user facilities. NSRCs will serve the Nation's researchers broadly and, as with the existing BES facilities, access to NSRCs will be through submission of proposals that will be reviewed by mechanisms established by the facilities themselves. Planning for the NSRCs includes substantial participation by the research community through a series of open, widely advertised workshops. Workshops held to date have been heavily attended, attracting up to 300 researchers. Funds are requested for the start of construction of the NSRC located at Oak Ridge National Laboratory and for the continuation of engineering and design for the NSRC located at Lawrence Berkeley National Laboratory and the NSRC at Sandia National Laboratories (Albuquerque) and Los Alamos National Laboratory. These NSRCs were chosen from among those proposed by a peer review process. Additional information on the NSRCs is provided in the construction project data sheet, project number 03-R-312 and in the PED data sheet, project number 02-SC-002.

The research efforts described in the first paragraph above will benefit significantly from these NSRCs. For example, the NSRC at Oak Ridge National Laboratory will provide direct access to sample preparation for neutron scattering, which is ideal for magnetic structures and for soft materials and residual stress in materials; Oak Ridge also has a combination of electron beam microcharacterization instruments that are needed to characterize nanoscale particles and dislocations. The NSRC at Lawrence Berkeley National Laboratory will provide synthesis capabilities to explore the phenomena of macromolecular conformation and assembly and will provided ready access to the Advanced Light Source and other characterization instruments. The NSRC at Sandia/Los Alamos National Laboratories will provide sample preparation capabilities for thin films, electron transport, patterning, and magnetic layered structures. This NSRC will also have an array of characterization instruments for nanoelectronics, thin films, and magnetic structures; in the case of magnetic materials, the NSRC will provide ready access to the National High Magnetic Field Laboratory at Los Alamos.

This research activity will also benefit by new work proposed in FY 2003 in the Advanced Scientific Computing Research (ASCR) program in the area of computational nanoscale science engineering and technology. ASCR will develop the specialized computational tools for nanoscale science.

Spallation Neutron Source (SNS) Project

The purpose of the SNS Project is to provide a next-generation short-pulse spallation neutron source for neutron scattering. The SNS will be used by researchers from academia, national and federal 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, earth sciences, and engineering. When completed in 2006, the SNS will be significantly more powerful (by about a factor of 10) than the best spallation neutron source now in existence -- ISIS at the Rutherford Laboratory in England. The facility will be used by 1,000-2,000 scientists and engineers annually. Interest in the scientific community in the SNS is increasing.

In FY 2001, two grants were awarded to universities for research requiring the design, fabrication, and installation of instruments for neutron scattering. These instruments will be sited at the SNS, with commissioning beginning late in FY 2006, shortly after the SNS facility itself is commissioned. Both awards were made based on competitive peer review conducted under 10 CFR Part 605, Financial

Assistance Program. An interagency working group was established under the auspices of the Office of Science and Technology Policy to coordinate the funding neutron scattering instruments at all of the neutron sources in view of the opportunity for new instruments at SNS. In addition to these two instruments, the BES program will provide $5,000,000 of Materials Sciences and Engineering subprogram funding for continuing the development of instruments to exploit the scientific potential of the SNS facility. These instruments will be built by individual DOE laboratories or consortia of DOE laboratories in collaboration with the SNS based on scientific merit and importance to users from universities, industries, and government laboratories.

Neutron scattering will play a role in all forms of materials research and design, including the development of smaller and faster electronic devices; lightweight alloys, plastics, and polymers for transportation and other applications; magnetic materials for more efficient motors and for improved magnetic storage capacity; and new drugs for medical care. The high neutron flux (i.e., high neutron intensity) from the SNS will enable broad classes of experiments that cannot be done with today's low-flux sources. For example, high flux enables studies of small samples, complex molecules and structures, time-dependent phenomena, and very weak interactions.

The SNS will consist of a linac-ring accelerator system that delivers short (microsecond) proton pulses to a target/moderator system where neutrons are produced by a process called spallation. The neutrons so produced are then used for neutron scattering experiments. Specially designed scientific instruments use these pulsed neutron beams for a wide variety of investigations. There will initially be one partially instrumented target station with the potential for adding more instruments and a second target station later.

The SNS project partnership among six DOE laboratories takes advantage of specialized technical capabilities within the laboratories: Lawrence Berkeley National Laboratory in ion sources; Los Alamos National Laboratory in linear accelerators; Thomas Jefferson National Accelerator Facility in superconducting linear accelerators; Brookhaven National Laboratory in proton storage rings; Argonne National Laboratory in instruments; and Oak Ridge National Laboratory in targets and moderators.

The SNS project has made progress during FY 2001 and the project continues to meet scheduled milestones and remains within budget. Project-wide, design work is about two-thirds complete, and R&D on technical components is nearing completion. Title II design of conventional facilities is nearly 100% complete. Site preparation has cleared the way for construction of the front end and target buildings, the linac tunnel, and a number of support buildings and utility systems. Procurements for technical components have been awarded with generally favorable cost results, and deliveries of some items to Oak Ridge have begun. Definitive plans have been developed for equipment installation and facility commissioning activities.

FY 2002 budget authority has been provided to continue R&D, design, procurement, and construction activities, and to begin component installation. Essentially all R&D supporting the construction of the SNS will be completed in FY 2002, with instrument R&D continuing throughout the project. Title II design will be completed on the linac, and will continue on the ring, target, and instrument systems. Equipment installation efforts will begin in the front end and the low energy sections of the linac. Other technical components for the linac, ring, target, and instruments will continue to be manufactured. Work on conventional facilities will continue. Some conventional facilities will reach completion and be made available for equipment installation, such as the front end building, and portions of the klystron building and linac tunnel. Construction work will begin on the ring tunnel.

FY 2003 funding is requested to continue instrument R&D and design, procurement, construction, and installation activities, and to begin system commissioning. The front end will be commissioned, and low-energy linac component installation and commissioning will commence. Other linac and ring components will begin to be delivered and installed in their respective tunnels. Target building construction and equipment installation will continue in concert with each other. Numerous conventional facilities including the klystron, central utilities, and ring service buildings as well as the linac and ring tunnels will be completed. All site utilities will be available to support linac commissioning activities.

The estimated Total Project Cost remains constant at $1,411,700,000 and the construction schedule continues to call for project completion by mid-2006. The estimate for annual operating costs has been updated to reflect more recent experience in the operation of major user facilities as well as in design, development, fabrication, maintenance, and user support of modern instruments. Additional information on the SNS Project is provided in the SNS construction project data sheet, project number 99-E-334.

The Linac Coherent Light Source (LCLS) Project

The purpose of the Linac Coherent Light Source (LCLS) Project is to provide laser-like radiation in the x-ray region of the spectrum that is 10 orders of magnitude (i.e., a factor of 10,000,000,000) greater in peak power and peak brightness than any existing coherent x-ray light source. This advance in brightness is similar to that of a synchrotron over a 1960's laboratory x-ray tube. Synchrotrons have revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be equally dramatic. The LCLS Project will provide the world's first demonstration of an x-ray free-electron-laser (FEL) in the 1.5 - 15 Å range.

For many years, the Basic Energy Sciences Advisory Committee (BESAC) has been actively involved with the development of such a next-generation light source. In 1997, the BESAC report *DOE Synchrotron Radiation Sources and Science* recommended funding an R&D program in next-generation light sources. In 1999, the BESAC report *Novel, Coherent Light Sources* concluded "Given currently available knowledge and limited funding resources, the hard x-ray region (8-20 keV or higher) is identified as the most exciting potential area for innovative science. DOE should pursue the development of coherent light source technology in the hard x-ray region as a priority. This technology will most likely take the form of a linac-based free electron laser using self-amplified stimulated emission or some form of seeded stimulated emission…"

The proposed LCLS will have properties vastly exceeding those of current x-ray sources in three key areas: peak brightness, coherence, and ultrashort pulses. The peak brightness of the LCLS is 10 orders of magnitude greater than current synchrotrons; the light is coherent or "laser like" enabling many new types of experiments; and the pulses are short (230 femtoseconds with planned improvements that will further reduce the pulse length) enabling studies of fast chemical and physical processes. These characteristics open new realms of scientific applications in the chemical, material, and biological sciences including fundamental studies of the interaction of intense x-ray pulses with simple atomic systems, structural studies on single nanoscale particles and biomolecules, ultrafast dynamics in chemistry and solid-state physics, studies of nanoscale structure and dynamics in condensed matter, and use of the LCLS to create plasmas.

The LCLS project leverages capital investments in the existing SLAC linac as well as technologies developed for linear colliders and for the production of intense electron beams with radio-frequency photocathode guns. The SLAC linac will provide high-current, low-emittance 5–15 GeV electron bunches at a 120 Hz repetition rate. When traveling through a newly constructed long undulator, the electron bunches will lead to self-amplification of the emitted x-ray radiation, constituting the x-ray FEL. The availability of the SLAC linac for the LCLS Project creates a unique opportunity (worldwide) for demonstration and use of x-ray FEL radiation.

The proposed LCLS Project requires a 150 MeV injector to be built at Sector 20 of the 30-sector SLAC linac to create the electron beam required for the x-ray FEL. The last one third of the linac will be modified by adding two magnetic bunch compressors. Most of the linac and its infrastructure will remain unchanged. The existing components in the Final Focus Test Beam tunnel will be removed and replaced by a new 120 meter undulator and associated equipment. The preliminary Total Estimated Cost (TEC) is in the range of $165,000,000 to $225,000,000. FY 2003 Project Engineering and Design (PED) funding of $6,000,000 is requested for Title I and Title II design work. Additional information on the LCLS Project is provided in the LCLS PED data sheet, project number 03-SC-002.

Research Using X-ray and Neutron Scattering

X-ray and neutron scattering are powerful tools used to investigate the fundamental properties of materials. BES is the major supporter of x-ray and neutron science in the United States and has pioneered the development of virtually all of the instruments and techniques used at these facilities for research in materials sciences, surface science, condensed matter physics, atomic and molecular physics, chemical dynamics, x-ray microscopy, tomography, femtosecond phenomena, interfacial/environmental, and geophysics studies. Within the physical sciences, BES remains the dominant federal supporter of beamline development and instrument fabrication providing as much as 85% of the federal support for these activities.

Major instruments at the synchrotron light sources and the neutron sources have a lifetime of 7-10 years after which the instruments undergo major upgrades or are retired. Thus, after a facility is fully instrumented, about 10-15% of the instruments must be upgraded or replaced each year to keep the facility at the forefront of science. In FY 2003, new funding in the amount of $17,292,000 is requested to support instrument upgrades, instrument replacements, and new instrumentation at the x-ray and neutron scattering facilities. Of these funds, $5,000,000 will be provided for instruments at the Spallation Neutron Source. These funds will be competed among both academic and laboratory institutions, and the resulting instruments and beamlines will be made available to the entire U.S. scientific research community.

Workforce Development

The BES program supports development of the R&D workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. In addition, the BES scientific user facilities provide outstanding hands-on research experience to many young scientists. Thousands of students and post-doctoral investigators are among the 8,000 researchers who conduct experiments at BES-supported facilities each year. The work that these young investigators perform at BES facilities is supported by a wide variety of sponsors including BES, other Departmental research programs, other federal agencies, and private institutions. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research and also provides talent for a wide variety of technical and industrial areas that require the problem solving abilities, computing skills, and technical skills developed through an education and experience in fundamental research.

This program supported graduate students and postdoctoral investigators in FY 2001 through grants or contracts; 4,046 graduate students and postdoctoral investigators used the BES science user facilities in FY 2001.

Funding Profile

(dollars in thousands)

	FY 2001 Comparable Appropriation	FY 2002 Original Appropriation	FY 2002 Adjustments	FY 2002 Comparable Current Appropriation	FY 2003 Request
Basic Energy Sciences					
Research					
Materials Sciences and Engineering	511,608	434,353	+78,169	512,522	547,883
Chemical Sciences, Geosciences, and Energy Biosciences	203,231	218,714	-10,931	207,783	220,146
Engineering and Geosciences	0	38,938	-38,938	0	0
Energy Biosciences	0	32,400	-32,400	0	0
Subtotal, Research	714,839	724,405	-4,100	720,305	768,029
Construction	258,929	279,300	0	279,300	251,571
Total, Basic Energy Sciences	973,768	1,003,705	-4,100	0	0
General Reduction	0	-4,100	4,100	0	0
Total, Basic Energy Sciences	973,768 [a] [b]	999,605	0	999,605	1,019,600

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

[a] Excludes $15,962,000 which was transferred to the SBIR program and $958,000 which was transferred to the STTR program.

[b] Excludes $991,000 which was transferred to the Science Safeguards and Security program in an FY 2001 reprogramming.

Funding by Site

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	24,205	22,738	23,041	+303	+1.3%
National Renewable Energy Laboratory	5,876	5,247	4,562	-685	-13.1%
Sandia National Laboratory	24,673	23,349	25,987	+2,638	+11.3%
Total, Albuquerque Operations Office	54,754	51,334	53,590	+2,256	+4.4%
Chicago Operations Office					
Ames Laboratory	17,961	16,114	16,507	+393	+2.4%
Argonne National Laboratory – East	159,028	154,389	152,734	-1,655	-1.1%
Brookhaven National Laboratory	75,942	56,606	57,398	+792	+1.4%
Chicago Operations Office	110,664	88,266	84,204	-4,062	-4.6%
Total, Chicago Operations Office	363,595	315,375	310,843	-4,532	-1.4%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	2,660	1,756	1,494	-262	-14.9%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	77,896	74,649	78,691	+4,042	+5.4%
Lawrence Livermore National Laboratory	5,643	4,793	4,676	-117	-2.4%
Stanford Linear Accelerator Center (SSRL)	34,691	31,643	41,716	+10,073	+31.8%
Oakland Operations Office	43,433	36,973	34,497	-2,476	-6.7%
Total, Oakland Operations Office	161,663	148,058	159,580	+11,522	+7.8%
Oak Ridge Operations Office					
Oak Ridge Institute For Science and Education	1,245	440	872	+432	+98.2%
Oak Ridge National Laboratory	374,386	391,333	343,176	-48,157	-12.3%
Oak Ridge Operations Office	39	0	0	0	--
Total, Oak Ridge Operations Office	375,670	391,773	344,048	-47,725	-12.2%
Richland Operations Office					
Pacific Northwest National Laboratory	13,024	11,346	11,648	+302	+2.7%
Washington Headquarters	2,402	79,963	138,397	+58,434	+73.1%
Total, Basic Energy Sciences	973,768 [a] [b]	999,605	1,019,600	+19,995	+2.0%

[a] Excludes $15,962,000 which was transferred to the SBIR program and $958,000 which was transferred to the STTR program.

[b] Excludes $991,000 which was transferred to the Science Safeguards and Security program in an FY 2001 reprogramming.

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 and Engineering subprogram supports experimental and theoretical research on rare earth elements in novel mechanical, magnetic, and superconducting materials. Ames scientists are experts on magnets, superconductors, and quasicrystals that incorporate rare earth elements. The BES Chemical Sciences, Geosciences, and Energy Biosciences subprogram supports theoretical studies for the prediction of molecular energetics and chemical reaction rates. Ames Laboratory provides leadership in analytical and separations chemistry.

Ames Laboratory is home to the **Materials Preparation Center** (MPC), which is dedicated to the preparation, purification, and characterization of rare-earth, alkaline-earth, and refractory metal and oxide materials. Established in 1981, the MPC is a one-of-a-kind resource that provides scientists at university, industrial, and government laboratories with research and developmental quantities of high-purity materials and unique analytical and characterization services that are not available from commercial suppliers. The MPC is renowned for its technical expertise in alloy design and for creating materials that exhibit ultrafine microstructures, high strength, magnets, and high conductivity. The MPC also operates the Materials Referral System and Hotline, where users may obtain free information from a database of over 2,500 expert sources for the preparation and characterization of a wide variety of commercial materials and research samples.

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 research activities in broad areas of materials and chemical sciences. It is also the site of three BES supported user facilities -- the Advanced Photon Source (APS), the Intense Pulsed Neutron Source (IPNS), and the Electron Microscopy Center for Materials Research (EMC).

The Materials Sciences and Engineering subprogram supports research in high-temperature superconductivity; polymeric superconductors; thin-film magnetism; surface science; the synthesis, advanced electron beam microcharacterization, and atomistic computer simulation of interfaces in advanced ceramic thin-films; defects and disordered materials; and synthesis and electronic and structural characterization of oxide ceramic materials, including high-temperature superconductors. The Chemical Sciences, Geosciences, and Energy Biosciences subprogram supports research in actinide separations; physical and chemical properties of actinide compounds; structural aspects fundamental to advanced electrochemical energy storage; the chemistry of complex hydrocarbons; experimental and theoretical studies of metal clusters of catalytically active transition metals; molecular dynamics of gas-phase chemical reactions of small molecules and radicals; photosynthesis mechanisms; atomic, molecular, and optical physics; organic geochemistry related to hydrocrbon formation, and computational microtomography of porous earth materials. ANL has one of three pulsed radiolysis activities that together form a national research program in this area. The other two are at Brookhaven National Laboratory and the University of Notre Dame.

The **Advanced Photon Source** is one of only three third-generation, hard x-ray synchrotron radiation light sources in the world, and it is the only one in the Americas. It is a world-class facility. Dedicated in 1996, the construction project was completed five months ahead of schedule and for less than the budget. The 7 GeV hard x-ray light source has since met or exceeded all technical specifications. For example, the APS is 10 times more brilliant than its original specifications and the vertical stability of the particle beam is three times better than its design goal. The 1,104-meter circumference facility -- large enough to house a baseball park in its center -- includes 34 bending magnets and 34 insertion devices, which generate a capacity of 68 independently controlled beamlines for experimental research. Beamlines are assigned to user groups in Collaborative Access Teams (CATs), whose proposals are reviewed and approved based on their scientific program and the criticality of high-brilliance x-rays to the work. These instruments attract researchers 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. The high-quality, reliable x-ray beams at the APS have already brought about new discoveries in materials structure.

The **Intense Pulsed Neutron Source** is a 30 Hz short-pulsed spallation neutron source that first operated all instruments in the user mode in 1981. Twelve neutron beam lines serve 14 instruments, one of which is a test station for instrument development. 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. 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. A recent BESAC review of this facility described it as a “reservoir of expertise with a track record of seminal developments in source and pulsed source instruments second to none” and noted that ANL is “fully committed from top to bottom to supporting the user program.” This is reflected by a large group of loyal, devoted users. Research at IPNS is conducted on the structure of high-temperature superconductors, alloys, composites, polymers, catalysts, liquids and non-crystalline materials, materials for advanced energy technologies, and biological materials. The staff of the IPNS is taking a leadership role in the design and construction of instrumentation for the Spallation Neutron Source at Oak Ridge National Laboratory.

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 both a tandem accelerator and an ion implanter in conjunction with a transmission electron microscope 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 an electron microscope permits direct, real-time, in-situ observation of the effects of ion bombardment of materials and consequently attracts users from around the world.

Brookhaven National Laboratory

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

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

The Chemical Sciences, Geosciences, and Energy Biosciences subprogram supports one of three national activities for pulsed radiolysis research at BNL. The innovative short-pulse radiation chemistry facility contributes to radiation sciences research across broad areas of chemistry. There is also research on the spectroscopy of reactive combustion intermediates and studies of the mechanisms of electron transfer related to artificial photosynthesis. Other chemistry 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, the formation of atmospheric aerosols and their reactivity, and the interactions of rock-fluid systems. Biosciences research activities include mechanistic and molecular-based studies on photosynthesis, lipid metabolism, and genetic systems.

The **National Synchrotron Light Source** (NSLS) is among the largest and most diverse scientific user facilities in the world. The NSLS, commissioned in 1982, has consistently operated at >95% reliability 24 hours a day, seven days a week, with scheduled periods for maintenance and machine studies. Adding to its breadth is the fact that the NSLS consists of two distinct electron storage rings. The x-ray storage ring is 170 meters in circumference and can accommodate 60 beamlines or experimental stations, and the VUV storage ring can provide 25 additional beamlines around its circumference of 51 meters. Synchrotron light from the x-ray ring is used to determine the atomic structure of materials using diffraction, absorption, and imaging techniques. Experiments at the VUV ring help solve the atomic and electronic structure as well as the magnetic properties of a wide array of materials. These data are fundamentally important to virtually all of the physical and life sciences as well as providing immensely useful information for practical applications. The petroleum industry, for example, uses the NSLS to develop new catalysts for refining crude oil and making by-products like plastics.

The **High Flux Beam Reactor**, commissioned in 1965, was a research reactor designed to produce neutrons for scattering. During its three decades of operation, the HFBR was a premier gathering spot for neutron scientists involved in a broad array of studies, including phonons in rare gases; ferromagnets and antiferromagnets; critical phenomena in magnetic transitions; structure and dynamics of molecules adsorbed on surfaces; direct measure of electron-phonon interaction in 'old' superconductors; structure determination of small sub-unit of ribosomes; critical phenomena in one- and two-dimensional magnets; impurity effects on phase transitions; incommensurate systems in metals and insulators; magnetic correlations in heavy fermions; magnetic superconductors; hydrogen location in amino acids and carbohydrate building blocks; static and dynamic correlations in high temperature superconductors; exotic behavior of one-dimensional magnets; shape memory materials; anomalous correlation lengths in phase transitions; and the structure of ceramics with negative thermal expansion. In December 1996, a plume of tritiated water was discovered emanating from a leak in the HFBR spent fuel pool, which contaminated the groundwater south of the reactor. The facility remained on standby until the Secretary of Energy announced on November 16, 1999, that the reactor would be permanently closed. Activities to place the reactor in a safe state awaiting full decommissioning by DOE's Office of Environmental Management were completed in FY 2001. The permanent shut down of the HFBR increases the importance of the remaining neutron sources in the U.S.

Idaho National Engineering and Environmental Laboratory

Idaho National Environmental and Engineering Laboratory (INEEL) is a Multiprogram Laboratory located on 572,000 acres in Idaho Falls, Idaho. The Materials Sciences and Engineering 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, and to develop new diagnostic techniques for engineering systems. The Chemical Sciences, Geosciences, and Energy Biosciences 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.

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. Collocated with the University of California at Berkeley, the Laboratory benefits from regular collaborations and joint appointments with numerous outstanding faculty members. The Laboratory is the home to the research of many students and postdoctoral appointees. 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 and Engineering subprogram supports research in laser spectroscopy, superconductivity, thin films, femtosecond processes, x-ray optics, biopolymers, polymers and composites, surface science, theory, and nonlinear dynamics. Research is carried out on new aluminum-based alloys containing geranium and silicon; the structures of magnetic, optical, and electrical thin films and coatings; processing, mechanical fatigue, and high-temperature corrosion of structural ceramics and ceramic coatings; mechanical behavior of metals; and the synthesis, structure, and properties of advanced semiconductor and semiconductor-metal systems. The Chemical Sciences, Geosciences, and Energy Biosciences subprogram supports fundamental, chemical dynamics research using molecular-beam techniques. Femtosecond spectroscopy studies of energy transfer on surfaces has also been developed. LBNL is recognized for its work in radiochemistry, the chemistry of the actinides, inorganic chemistry, and both homogeneous and heterogeneous chemical catalysis. Experimental and computational geosciences research is supported on coupled reactive fluid flow and transport properties and processes in the subsurface, and how to track and image them. In particular, geochemical studies focus on experimental and modeling studies on critical shallow earth mineral systems, improving analytical precision in synchrotron x-ray studies, and improving our understanding of how isotopic distributions act as tracers for geologic processes and their rates. Biosciences research focuses on the physics of the photosynthetic apparatus and on the formation of subcellular organelles.

The **Advanced Light Source** (ALS) began operations in October 1993 and now serves over 1,000 users as one of the world's brightest sources of high-quality, reliable vacuum-ultraviolet (VUV) light and long-wavelength (soft) x-rays. Soft x-rays and VUV light are used by the researchers at the ALS as high-resolution tools for probing the electronic and magnetic structure of atoms, molecules, and solids, such as those for high-temperature superconductors. The high brightness and coherence of the ALS light are particularly suited for soft x-ray imaging of biological structures, environmental samples, polymers, magnetic nanostructures, and other inhomogeneous materials. Other uses of the ALS include holography, interferometry and the study of molecules adsorbed on solid surfaces. The pulsed nature of the ALS light offers special opportunities for time resolved research, such as the dynamics of chemical reactions. Shorter wavelength (intermediate-energy) x-rays are also used at structural biology experimental stations for x-ray crystallography and x-ray spectroscopy of proteins and other important biological macromolecules. The ALS is a growing facility with a lengthening portfolio of beamlines that have already been applied to make important discoveries in a wide variety of scientific disciplines.

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. This facility contains one of the highest resolution electron microscopes in the U.S.

The **Molecular Foundry**, a planned BES Nanoscale Science Research Center and a current PED project, will support research and the operation of a user facility for the design, modeling, synthesis, processing, fabrication and characterization of novel molecules and nanoscale materials. The facility will provide laboratories for materials science, physics, chemistry, biology, and molecular biology. State-of-the-art equipment will include a class 100 clean room, controlled environmental rooms, scanning tunneling microscopes, atomic force microscopes, transmission electron microscope, fluorescence microscopes, mass spectrometers, DNA synthesizer and sequencer, nuclear magnetic resonance spectrometer, ultrahigh vacuum scanning-probe microscopes, photo, uv, and e-beam lithography equipment, peptide synthesizer, advanced preparative and analytical chromatographic equipment, and cell culture facilities.

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 42 miles 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 and Engineering subprogram supports research in positron materials science, superplasticity in alloys, adhesion and bonding at interfaces, kinetics of phase transformations in welds. The Chemical Sciences, Geosciences, and Energy Biosciences subprogram supports plasma assisted catalysis for environmental control of pollutants, geosciences research on the source(s) of electromagnetic responses in crustal rocks, seismology theory and modeling, the mechanisms and kinetics of low-temperature geochemical processes and the relationships among reactive fluid flow, geochemical transport and fracture permeability.

Los Alamos National Laboratory

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

The Materials Sciences and Engineering subprogram supports research on strongly correlated electronic materials, high-magnetic fields, microstructures, deformation, alloys, bulk ferromagnetic glasses, mechanical properties, ion enhanced synthesis of materials, metastable phases and microstructures, and mixtures of particles in liquids. The Chemical Sciences, Geosciences, and Energy Biosciences subprogram supports research to understand the electronic structure and reactivity of actinides through the study of organometallic compounds. Also supported is work to understand the chemistry of plutonium and other light actinides in both near-neutral pH conditions and under strongly alkaline conditions relevant to radioactive wastes and research in physical electrochemistry fundamental to energy storage systems. In the areas of geosciences, experimental and theoretical research is supported on rock physics, seismic imaging, the physics of the earth's magnetic field, fundamental geochemical studies of isotopic equilibrium/disequilibrium, and mineral-fluid-microbial interactions.

The **Los Alamos Neutron Science Center** provides an intense pulsed source of neutrons for both national security research and civilian research. LANSCE is comprised of a high-power 800-MeV proton linear accelerator, a proton storage ring, production targets to the Manuel Lujan Jr. Neutron Scattering Center and the Weapons Neutron Research facility, and a variety of associated experiment areas and spectrometers. The Lujan Center features instruments for measurement of high-pressure and high-temperature samples, strain measurement, liquid studies, and texture measurement. The facility has a long history and extensive experience in handling actinide samples. A new 30 Tesla magnet is available for use with neutron scattering to study samples in high-magnetic fields.

The **Center for Integrated Nanotechnologies (CINT)**, a planned BES Nanoscale Science Research Center, will focus on exploring the path from scientific discovery to the integration of nanostructures into the micro- and macroworlds. This path involves experimental and theoretical exploration of behavior, understanding new performance regimes and concepts, testing designs, and integrating nanoscale materials and structures. CINT focus areas are nanophotonics and nanoelectronics, complex functional nanomaterials, nanomechanics, and the nanoscale/bio/microscale interfaces. CINT will be jointly administered by Los Alamos National Laboratory and Sandia National Laboratory. This Center will make use of a wide range of specialized facilities including the Los Alamos Neutron Science Center and the National High Magnetic Field Laboratory at LANL.

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 and Engineering subprogram supports basic research efforts that underpin this technological emphasis at the Laboratory, for example on overcoming semiconductor doping limits, novel and ordered semiconductor alloys, theoretical and experimental studies of properties of advanced semiconductor alloys for prototype solar cells. The Chemical Sciences, Geosciences, and Energy Biosciences 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.

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 administrative support for panel reviews and site reviews commissioned and led by the BES program staff. ORISE also assists with the administration of topical scientific workshops and provides administrative support for other activities such as for the reviews of BES construction projects. ORISE manages the **Shared Research Equipment (SHaRE)** program at ORNL. The SHaRE program makes available state-of-the-art electron beam microcharacterization facilities for collaboration with researchers from universities, industry and other government laboratories.

Oak Ridge National Laboratory

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

ORNL has perhaps the most comprehensive materials research program in the country. The Materials Sciences and Engineering subprogram supports basic research that underpins technological efforts such as those supported by the energy efficiency program. Research is conducted in microscopy and microanalysis, atomistic mechanisms in interface science, theoretical studies of metals, alloys, and ceramics, theory and design of dual phase alloys, radiation effects, domain structure in epitaxial ferroelectrics, semiconductor nanocrystals for carbon dioxide fixation, high temperature alloy design, welding science, microstructural design of advanced ceramics, acoustic harmonic generation, non-equilibrium processes. Research is also conducted in superconductivity, magnetic materials, neutron scattering and x-ray scattering, electron microscopy, pulsed laser ablation, thin films, lithium battery materials, thermoelectric materials, surfaces, polymers, structural ceramics, alloys; and intermetallics. The subprogram emphasizes experiments at HFIR and other specialized research facilities that include the High Temperature Materials Laboratory, the Shared Research Equipment (SHaRE) program, and the Surface Modification and Characterization (SMAC) facility. The SMAC facility is equipped with ion implantation accelerators that can be used to change the physical, electrical, and chemical properties of solids to create unique new materials not possible with conventional processing techniques. Surface modification research has led to important practical applications of materials with improved friction, wear, catalytic, corrosion, and other properties. Engineering research provides support for computational nonlinear sciences.

The Chemical Sciences, Geosciences, and Energy Biosciences subprogram supports research in analytical chemistry, particularly in the area of mass spectrometry, separation chemistry, and thermophysical 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 subprogram also supports research on the collision physics of highly charged ions and their interactions with surfaces. In the area of geosciences, work is supported to study low-temperature geochemical processes and rates in mineral-fluid systems.

The **High Flux Isotope Reactor** is a light-water cooled and moderated reactor that began full-power operations in 1966. HFIR operates at 85 megawatts to provide state-of-the-art facilities for neutron scattering, materials irradiation, and neutron activation analysis and is the world's leading source of elements heavier than plutonium for research, medicine, and industrial applications. The neutron-scattering experiments at HFIR reveal the structure and dynamics of a very wide range of materials. The neutron-scattering instruments installed on the four horizontal beam tubes are used in fundamental studies of materials of interest to solid-state physicists, chemists, biologists, polymer scientists, metallurgists, and colloid scientists. Recently, a number of improvements at HFIR have increased its neutron scattering capabilities to 14 state-of-the-art neutron scattering instruments on the world's brightest beams of steady-state neutrons. These upgrades include the installation of larger beam tubes and shutters, a high-performance liquid hydrogen cold source, and neutron scattering instrumentation. The new installation of the cold source provides beams of cold neutrons for scattering research that are as bright as any in the world. Use of these forefront instruments by researchers from universities, industries, and government laboratories are granted on the basis of scientific merit.

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

The **Center for Nanophase Materials Sciences (CNMS)**, a proposed BES Nanoscale Science Research Center construction project, will establish a research center and user facility that will integrate nanoscale science research with neutron science, synthesis science, and theory/modeling/simulation. A new building will provide state-of-the-art clean rooms, general laboratories, wet and dry laboratories for sample preparation, fabrication and analysis. Included will be equipment to synthesize, manipulate, and characterize nanoscale materials and structures. The facility, which will be collocated with the Spallation Neutron Source complex, will house over 100 research scientists and an additional 100 students and postdoctoral fellows. The CNMS's major scientific thrusts will be in nano-dimensioned soft materials, complex nanophase materials systems, and the crosscutting areas of interfaces and reduced dimensionality that become scientifically critical on the nanoscale. A major focus of the CNMS will be to exploit ORNL's unique capabilities in neutron scattering to determine the structure of nanomaterials, to develop a detailed understanding of synthesis and self-assembly processes in "soft" materials, and to study and understand collective (cooperative) phenomena that emerge on the nanoscale.

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, Geosciences, and Energy Biosciences subprogram supports research in 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. Included among these studies are high-resolution laser spectroscopy for analysis of trace metals on ultra small samples; understanding of the fundamental inter- and intra-molecular effects unique to solvation in supercritical fluids; and interfacing theoretical chemistry with experimental methods to address complex questions in catalysis. Geosciences research includes theoretical and experimental studies to improve our understanding of phase change phenomena in microchannels. The Materials Sciences and Engineering subprogram supports research on molecularly tailored nanostructured materials, stress corrosion and corrosion fatigue, interfacial dynamics during heterogeneous deformation, irradiation assisted stress corrosion cracking, bulk defect and defect processing in ceramics, chemistry and physics of ceramic surfaces and interfacial deformation mechanisms in aluminum alloys.

Sandia National Laboratory

Sandia National Laboratory (SNL) is a Multiprogram Laboratory located on 3,700 acres in Albuquerque, New Mexico (SNL/NM), with sites in Livermore, California (SNL/CA), and Tonopah, Nevada. SNL is home to significant research efforts in materials and chemical sciences with additional programs in engineering and geosciences. SNL/CA 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. The Materials Sciences and Engineering subprogram supports projects on the physics and chemistry of ceramics, adhesion and interfacial wetting, localized corrosion initiation, long range particle interactions and collections phenomena in plasma and colloidal crystals, advanced epitaxial growth techniques, energetic particle synthesis, artificially structured semiconductors, field structured anisotropic composites, surface interface and bulk properties of advanced ceramics, transitions in the strongly collective behavior of dislocations, and mixtures of particles in liquids. The Chemical Sciences, Geosciences, and Energy Biosciences subprogram supports geosciences research on mineral-fluid reactivity, rock mechanics, reactive fluid flow and particulate flow through fractured and porous media, and seismic and electromagnetic imaging and inversion studies.

The **Combustion Research Facility** at SNL/CA is an internationally recognized facility for the study of combustion science and technology. In-house efforts combine theory, modeling, and experiment including diagnostic development, kinetics, and dynamics. 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. Basic research supported by the Chemical Sciences, Geosciences, and Energy Biosciences subprogram is often done in close collaboration with applied problems. 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.

The **Center for Integrated Nanotechnologies (CINT)**, a planned BES Nanoscale Science Research Center, will focus on exploring the path from scientific discovery to the integration of nanostructures into the micro- and macroworlds. This path involves experimental and theoretical exploration of behavior, understanding new performance regimes and concepts, testing designs, and integrating nanoscale materials and structures. CINT focus areas are nanophotonics and nanoelectronics, complex functional nanomaterials, nanomechanics, and the nanoscale/bio/microscale interfaces. CINT will be jointly administered by Los Alamos National Laboratory and Sandia National Laboratory. This Center will make use of a wide range of specialized facilities including the Los Alamos Neutron Science Center and the National High Magnetic Field Laboratory at LANL.

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 and use for synchrotron studies 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. In FY 2000, the facility was comprised of 32 experimental stations and was used by nearly 900 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 and Engineering subprogram supports a research program at SSRL with emphasis in both the x-ray and ultraviolet regions of the spectrum. SSRL scientists are experts in photoemission studies of high-temperature superconductors and in x-ray scattering. The SPEAR 3 upgrade at SSRL will provide major improvements that will increase the brightness of the ring for all experimental stations.

The **Linac Coherent Light Source (LCLS)** will provide laser-like radiation in the x-ray region of the spectrum that is 10 orders of magnitude (i.e., a factor of 10,000,000,000) greater in peak power and peak brightness than any existing coherent x-ray light source. The SLAC linac will provide high-current, low-emittance 5–15 GeV electron bunches at a 120 Hz repetition rate. A newly constructed long undulator will bunch the electrons, leading to self-amplification of the emitted x-ray radiation, constituting the x-ray FEL. The availability of the SLAC linac for the LCLS Project creates a unique opportunity (worldwide) for demonstration and use of x-ray FEL radiation.

All Other Sites

The BES program funds research at 172 colleges/universities located in 49 states. Also included are funds for research awaiting distribution pending completion of peer review results.

Materials Sciences and Engineering

Mission Supporting Goals and Objectives

The Materials Sciences and Engineering subprogram delivers the scientific knowledge and discoveries in the materials sciences and engineering that underpin DOE's missions in science, energy, environmental quality, and national security; extends the frontiers of condensed matter physics, metal and ceramic sciences, and materials chemistry, and materials engineering in order to expand the scientific foundations for the development of materials that improve the efficiency, economy, environmental acceptability, and safety in energy generation, conversion, transmission, and use; and plans, constructs, and operates major scientific user facilities to serve researchers at universities, national laboratories, and industrial laboratories.

The Materials Sciences and Engineering subprogram supports basic research in condensed matter physics, metal and ceramic sciences, materials chemistry, and materials engineering. This 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 magnetic materials, semiconductors, superconductors, metals, ceramics, alloys, polymers, metallic glasses, ceramic matrix composites, catalytic materials, surface science, corrosion, neutron and x-ray scattering, chemical and physical properties, welding and joining, non-destructive evaluation, electron beam microcharacterization, nanotechnology and microsystems, fluid dynamics and heat transfer in materials, nonlinear systems, 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. For example, the fuel economy in automobiles is directly proportional to the weight of the automobile, and fundamental research on strength of materials has led to stronger, lighter materials, which directly affects fuel economy. The efficiency of a combustion engine is limited by the temperature and strength of materials, and fundamental research on alloys and ceramics has led to the development of materials that retain their strength at high temperatures. Research in semiconductor physics has led to substantial increases in the efficiency of photovoltaic materials for solar energy conversion. Fundamental research in condensed matter physics and ceramics has underpinned the development of practical high-temperature superconducting wires for more efficient transmission of electric power. This subprogram is a premier sponsor of condensed matter and materials physics in the U.S., is the primary supporter of the BES user facilities, and is responsible for the construction of the Spallation Neutron Source. **Performance will be measured by** reporting accomplishments on the common performance measures on leadership, excellence, and relevance; quality; and safety and health.

Funding Schedule

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Materials Sciences and Engineering Research	228,141	236,842	261,028	+24,186	+10.2%
Facilities Operations	283,467	263,865	274,118	+10,253	+3.9%
SBIR/STTR	0	11,815	12,737	+922	+7.8%
Total, Materials Sciences and Engineering	511,608	512,522	547,883	+35,361	+6.9%

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Materials Sciences and Engineering Research	**228,141**	**236,842**	**261,028**
▪ **Structure and Composition of Materials**	**33,767**	**36,070**	**36,697**

This activity supports basic research in the structure and characterization of materials; the relationship of structure to the behavior and performance of materials; predictive theory and modeling; and new materials such as bulk metallic glasses and nanophase materials. This activity also supports four electron beam microcharacterization user centers: the Center for Microanalysis of Materials at the University of Illinois, the Electron Microscopy Center for Materials Research at Argonne National Laboratory, the National Center for Electron Microscopy at Lawrence Berkeley National Laboratory, and the Shared Research Equipment Program at Oak Ridge National Laboratory. These network-interfaced centers contain a variety of highly specialized instruments to characterize localized atomic positions and configurations, chemical gradients, interatomic bonding forces, etc.

The properties and performance of materials used in all areas of energy technology depend upon their structure. Performance improvements for environmentally acceptable energy generation, transmission, storage, and conversion technologies likewise depend upon the structural characteristics of advanced materials. This dependency occurs because the spatial and chemical inhomogeneities in materials (e.g. dislocations, grain boundaries, magnetic domain walls and precipitates, etc.) determine and control critical behaviors such as fracture toughness, ease of fabrication by deformation processing, charge transport and storage capacity, superconducting parameters, magnetic behavior, and corrosion susceptibility, etc.

In FY 2003, major activities will be responsive to the need for advanced instruments with capabilities to characterize and interpret atomic configurations and packing arrangements at the nanoscale with improved resolution and accuracy, including the ability to determine composition, bonding, and physical properties of materials. Many of these advanced tools will come from the further development of current microscopies; however, new instruments are needed as well. Additional funding is requested to address one of the major recommendations of BESAC following its FY 2000 review of the electron beam microcharacterization centers for the design of components for an aberration corrected transmission electron microscope. This instrument would advance understanding in many areas related to energy mission needs such as interfaces in solid-state devices, load-bearing

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

structural composites and protective coatings; deformation behavior that relates to the processing of metals; grain boundary sliding that degrades the strength of structural alloys and ceramics at elevated temperatures; domain walls in ferromagnetic and ferroelectric materials; vortices and flux pinning in superconductors; and long-standing problems of brittle fracture and fracture resistance. Additional funding is also requested to address another BESAC recommendation to enhance the remote telepresence operations at the electron beam microcharacterization centers.

Capital equipment is provided for items such as new electron microscopes and improvements to existing instruments.

	FY 2001	FY 2002	FY 2003
▪ **Mechanical Behavior and Radiation Effects**............................	**15,286**	**14,530**	**14,530**

This activity supports basic research to understand the mechanical behavior of materials under static and dynamic stresses and the effects of radiation on materials properties. The objective is to understand at the atomic level the relationship between mechanical properties and defects in materials, including defect formation, growth, migration, and propagation. In the area of mechanical behavior, the research aims to build on this atomic level understanding in order to develop predictive models for the design of materials having prescribed mechanical behavior, with some emphasis on very high temperatures. In the areas of radiation effects, the research aims to advance atomic level understanding of amorphization mechanisms (transition from crystalline to a non-crystalline phase) to predict and suppress radiation damage, develop radiation-tolerant materials, and modify surfaces by such techniques as ion implantation.

This program contributes to DOE missions in the areas of fossil energy, fusion energy, nuclear energy, transportation systems, industrial technologies, defense programs, radioactive waste storage, energy efficiency, and environment management. This research helps understand 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. This activity relates to energy production and conversion through the need for failure resistant materials that perform reliably in the hostile and demanding environments of energy production and use. In an age when economics require life extension of materials and environmental and safety concerns demand reliability, the ability to predict performance from a fundamental basis is a priority. Furthermore, high energy-conversion efficiency requires materials that maintain their structural integrity at high operating temperatures. This program contributes to understanding of mechanical properties of materials and aspects of nuclear technologies ranging from radioactive waste storage to extending the lifetime of nuclear facilities.

In FY 2003, major activities will include continued development of experimental techniques and methods for the characterization of mechanical behavior, the development of a universal model for mechanical behavior that includes all length scales from atomic to nanoscale to bulk dimensions, and advancement of computer simulations for modeling behavior and radiation induced degradation.

Capital equipment is provided for items such as in-situ high-temperature furnaces, and characterization instrumentation.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Physical Behavior of Materials**...	**16,449**	**15,735**	**15,735**

This activity supports basic research at the atomic and molecular level to understand, predict, and control physical behavior of materials by developing rigorous models for the response of materials to environmental stimuli such as temperature, electromagnetic field, chemical environment, and proximity of surfaces or interfaces. Included within the activity are research in aqueous, galvanic, and high-temperature gaseous corrosion and their prevention; photovoltaics and photovoltaic junctions and interfaces for solar energy conversion; the relationship of crystal defects to the superconducting properties 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.

Research underpins the mission of DOE by developing the basic science necessary for improving the reliability of materials in mechanical and electrical applications and for improving the generation and storage of energy. With increased demands being placed on materials in real-world environments (extreme temperatures, strong magnetic fields, hostile chemical environments, etc), understanding how their behavior is linked to their surroundings and treatment history is critical.

In FY 2003, major activities will continue fundamental studies of corrosion resistance and surface degradation; semiconductor performance; high-temperature superconductors; and the interactions, and transport of defects in crystalline matter.

Capital equipment is provided for items such as spectroscopic instruments, instruments for electronic and magnetic property measurement, and analytical instruments for chemical and electrochemical analysis.

▪ **Synthesis and Processing Science**	**12,801**	**14,690**	**18,595**

This activity supports basic research on understanding and developing innovative ways to make materials with desired structure, properties, or behavior. Examples include materials synthesis and processing to achieve new or improved behavior, for minimization of waste, and for hard and wear resistant surfaces; high-rate, superplastic forming of light-weight metallic alloys for fuel efficient vehicles; high-temperature structural ceramics and ceramic matrix composites for high-speed cutting tools and fuel efficient and low-pollutant engines; non-destructive analysis for early warning of impending failure and flaw detection during production; response of magnetic materials to applied static and cyclical stress; plasma, laser, charged particle beam surface modification to increase corrosion resistance; and processing of high-temperature, intermetallic alloys.

The activity includes the operation of the Materials Preparation Center at the Ames Laboratory, which develops innovative and superior processes for materials preparation and provides small quantities of unique, research-grade materials that are not otherwise available to academic, governmental, and industrial research communities.

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.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

In FY 2003, new funding is requested for new research on nanoscale synthesis and processing. The mechanical properties of materials change dramatically as the grain size in polycrystalline materials approaches the nanometer scale. At conventional grain sizes a gain in strength of a material typically results in a loss in both ductility and fracture toughness resulting in a brittle material; however, by using nanocomposites and understanding deformation physics, we should be able to make materials that are both strong, tough (resistant to impact fracture) and ductile. The classical law for predicting the dependence of mechanical strength on particle, crystal or grain size appears to break down in the size regime of about 10 to 100 nanometers. A fundamental understanding of both deformation and embrittlement will require new tools, including massively parallel processing computers, techniques for establishing activation energies from atomistic calculations, methods for simplifying computations involving dislocation configurations and networks, electron microscopy, and direct, real-time dislocation studies (densities, types, and patterning). Deformation and fracture are very important to DOE. Embrittlement is a major cause of catastrophic failure in materials. Plastic deformation, which requires ductility, is used for almost all fabrication of structural metals (rolling, spinning, forging, extruding, and drawing); and plastic deformation can also change critical dimensions of materials in energy systems exposed to high temperatures, mechanical loads, or irradiation. Scientific and technological breakthroughs in materials research and development are very often directly coupled to progress in synthesis and processing. A way to control the size, size distribution and assembly of nanoparticles is to use patterns on surfaces. If successful, these assemblies could be used for solar energy conversion, efficient lighting, very sensitive sensors, nanoelectronic devices, improved corrosion and wear resistance and very high-density magnetic information storage. There is also great need for nanoparticles of uniform size, composition, and surface stability because experiments have shown that fracture toughness may undergo a profound increase as the grain size falls below 10 to 50 nm in high-temperature structural ceramics. These materials might be used in advanced fuel efficient engines, turbines, and machine cutting tools

Capital equipment includes furnaces, lasers, processing equipment, plasma and ion sources, and deposition equipment.

▪ **Engineering Research**...	**17,352**	**16,480**	**16,480**

This activity focuses on nanotechnology and microsystems; multi-component fluid dynamics and heat transfer; and non-linear dynamic systems. In the area of nanoscience, work focuses on nanomechanics and nano to micro assembly, networks of nano sensors, hybrid microdevices, energy transport and conversion, nanobioengineering, nucleation and nanoparticle engineering issues.

In FY 2003, efforts will continue in select topics of nano-engineering; predictive non-destructive evaluation of structures coupled with micromechanics and nano/microtechnology; multi-phase flow and heat transfer; system sciences, control, and instrumentation; and data and engineering analysis.

▪ **Neutron and X-ray Scattering**	**31,682**	**40,611**	**54,377**

This activity supports basic research in condensed matter physics and materials physics using neutron and x-ray scattering capabilities, primarily at major BES-supported user facilities. Research seeks to achieve a fundamental understanding of the atomic, electronic, and magnetic structures of materials as well as the relationship of these structures and excitations to the physical properties of materials. The

	(dollars in thousands)	
FY 2001	FY 2002	FY 2003

increasing complexity of such energy-relevant materials as superconductors, semiconductors, and magnets requires ever more sophisticated neutron and x-ray scattering techniques to extract useful knowledge and develop new theories for the behavior of these materials. Both ordered and disordered materials are of interest as are strongly correlated electron systems, surface and interface phenomena, and behavior under environmental variables such as temperature, pressure, and magnetic field. Neutron and x-ray scattering, together with the electron scattering probes supported under Structure and Composition of Materials, are the primary tools for characterizing the atomic, electronic and magnetic structures of materials.

Included within this request are funds to increase x-ray and neutron science activities in the U.S. based on BES reviews of the synchrotron radiation light sources, on discussions within the OSTP Interagency Working Group on Neutron Science, and on three BESAC reviews that addressed the current status of research activities using neutron scattering in the U.S. and strategies needed to take full advantage of the SNS upon its completion. Funding is increased for new and upgraded instrumentation to take advantage of scientific opportunities in the physical sciences and to leverage the multibillion-dollar investment in these facilities. Funds will be competed among both laboratory and academic institutions for multiyear beamline and instrument development projects in the range $5,000,000-15,000,000 each in such areas as materials sciences, surface science, condensed matter physics, atomic and molecular physics, polymers and soft materials, nanostructured materials, x-ray microscopy, tomography, femtosecond phenomena, interfacial studies, and imaging. Of these funds, $5,000,000 is provided for the development of instrumentation to exploit the scientific potential of the SNS facility. These instruments will be built by individual DOE laboratories or consortia of DOE laboratories and the SNS based on scientific merit and importance to users from universities, industries, and government laboratories. Funding is also increased for academic scientists to participate in the development of neutron scattering instruments and for the neutron science/scattering programs at the host institutions of the BES facilities, where historically the interplay between science programs and instrument design and fabrication has produced advances in instrumentation and seminal scientific results.

Capital equipment is provided for items such as detectors, monochromators, mirrors, and beamline instrumentation at all of the facilities.

	FY 2001	FY 2002	FY 2003
▪ **Experimental Condensed Matter Physics**	**35,837**	**34,115**	**38,020**

This activity supports a broad-based experimental program in condensed matter and materials physics with selected emphasis in the areas of electronic structure, surfaces/interfaces, and new materials. Research includes measurements of the properties of solids, liquids, glasses, surfaces, thin films, artificially structured materials, self-organized structures, and nanoscale structures. The materials examined include magnetic materials, superconductors, semiconductors and photovoltaics, liquid metals and alloys, and complex fluids. The development of new techniques and instruments including magnetic force microscopy, electron microscopic techniques, and innovative applications of laser spectroscopy is a major component of this activity. Measurements will be made under extreme conditions of temperature, pressure, and magnetic field - especially with the availability of the 100 Tesla pulsed field magnet at LANL.

This research is aimed at a fundamental understanding of the behavior of materials that underpin DOE technologies. Presently, the portfolio includes specific research thrusts in magnetism, semiconductors, superconductivity, materials synthesis and crystal growth, and photoemission spectroscopy. The portfolio addresses well-recognized needs, including understanding magnetism and superconductivity; the control of electrons and photons in solids; understanding materials at reduced dimensionality; the physical properties of large, interacting systems; and the properties of materials under extreme conditions.

The combined projects in superconductivity comprise a concerted and comprehensive energy-related research program. The DOE laboratories anchor the BES multi-disciplinary basic research efforts and maintain integration with the Energy Efficiency (EE) program applied and developmental efforts. Research on magnetism and magnetic materials focuses on hard magnet materials, such as those used for permanent magnets and in motors. This activity provides direct research assistance to the technology programs in Energy Efficiency and Renewable Energy (EE/RW) (photovoltaics, superconductivity, power sources), (thermoacoustics), and in National Nuclear Security Administration (NNSA) (photoemission, positron research, and electronic and optical materials). In addition, it supports, more fundamentally, several DOE technologies and the strategically important information technology and electronics industries through its results in the fields of semiconductor physics, ion implantation and electronics research; the petroleum recovery efforts of Fossil Energy and the clean-up efforts of Environmental Management (EM) programs through research on granular materials and on fluids; through EE research on advanced materials and magnets; energy conservation efforts through research on ion implantation, ultra-hard materials, superconductivity, thermoelectrics, and power source component materials; and NNSA through research on advanced laser crystals and weapons-related materials.

In FY 2003, new funding is requested for increased effort in experimental condensed matter physics to answer very fundamental questions in condensed matter physics at the nanoscale. As the size of a nanoscale structure becomes less than the average length for scattering of electrons or phonons, new modes of transport for electrical current and/or heat become possible. Also thermodynamic properties, including collective phenomena and phase transitions such as ferromagnetism, ferroelectricity, and superconductivity can change when structures contain a small number of atoms. The potential impacts of understanding the physics are very significant. For example, nanoscale structures provide a path toward the next generation of powerful permanent magnets for more efficient electric motors, better thermoelectric materials, and materials for more efficient solar energy conversion. In the case of soft materials, the physics of association and configuration of large molecules is poorly understood. Yet this kind of self assembly, which ubiquitous in nature, will be required for many of the potential applications of nanoscale science. Even the most rudimentary steps, such as how a macromolecule finds its equilibrium shape, are still in controversy. Much less is known about how such molecules can assemble into larger structures with defined shapes. Self-assembled macromolecules can provide very strong, lightweight materials that would decrease the weight in automobiles improving fuel economy.

Capital equipment is provided for crystal growth equipment, scanning tunneling microscopes, electron detectors for photoemission experiments, sample chambers, superconducting magnets and computers.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Condensed Matter Theory**	**16,124**	**18,007**	**18,007**

This activity supports basic research in theory, modeling, and simulations, and it complements the experimental work. The links between the electronic, optical, mechanical, and magnetic properties of nanostructures and their size, shape, topology, and composition are not well understood. For the simplest semiconductor systems, carbon nanotubes, and similar "elementary" systems, there has been considerable progress. However, for more complex materials and hybrid structures, even the outlines of a theory remain to be made. Computer simulations will play a major role in understanding materials at the nanometer scale and in the development "by design" of new nanoscale materials and devices. The greatest challenges and opportunities are in the transition regions where nanoscale phenomena are just beginning to emerge from the macroscopic and microscale regimes, which may be described by bulk properties plus the effects of interfaces and lattice defects.

This activity also supports the Center for X-ray Optics at LBNL, the Center for Advanced Materials at LBNL, the Surface Modification and Characterization Facility at ORNL, and the Center for Synthesis and Processing of Advanced Materials, which consists of collaborating projects at national laboratories, universities, and industry.

In FY 2003, this activity will provide support for theory, modeling and large-scale computer simulation to explore new nanoscale phenomena and the nanoscale regime. Also supported is the Computational Materials Sciences Network for studies of such topics as polymers at interfaces; fracture mechanics - understanding ductile and brittle behavior; microstructural evolution and microstructural effects on mechanics of materials, magnetic materials, modeling oxidation processes at surfaces and interfaces, and excited state electronic structure and response functions.

Capital equipment is provided for items such as computer workstations, beamline instruments, ion implantation and analytical instruments.

▪ **Materials Chemistry**	**30,808**	**27,650**	**29,602**

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. Research topics supported include solid state chemistry, surface chemistry, polymer chemistry, crystallography, synthetic chemistry, and colloid chemistry. Also supported are investigations of novel materials such as low-dimensional, self-assembled monolayers; polymeric conductors; organic superconductors and magnets; complex fluids; and biomolecular materials. The research employs a wide variety of experimental techniques to characterize these materials, including x-ray photoemission and other spectroscopies, scanning tunneling and atomic force microscopies, nuclear magnetic resonance, and x-ray and neutron reflectometry. The activity also supports the development of new experimental techniques, such as high-resolution magnetic resonance imaging without magnets, neutron reflectometry, and atomic force microscopy of liquids.

The research underpins many technological areas, such as batteries and fuel cells, catalysis, friction and lubrication, membranes, electronics, and environmental chemistry. New techniques for fabrication of nanocrystals, such as a unique inverse micellar process, make possible the efficient elimination of

	(dollars in thousands)	
FY 2001	FY 2002	FY 2003

dangerous chlorinated organic and phenolic pollutants (e.g., PCPs). Research on solid electrolytes has led to very thin rechargeable batteries that can be recharged many more times than existing commercial cells. Research on chemical vapor deposition (CVD) continues to impact the electronics industry. The development of synthetic membranes using biological synthesis may yield materials for separations and energy storage, and research on polymers may lead to light-weight structural materials which can be used in automobiles and thereby providing substantial savings in energy efficiency.

In FY 2003, work will continue on the systematic and parallel patterning of matter on the nanometer scale. There are many powerful approaches to patterning on the nanoscale that are fundamentally serial in nature, for instance, atom manipulation using scanning probe tips or electron beam lithography. The research in this activity will focus on methods to prepare macroscopic quantities of nanoscale components in complex, designed patterns, using techniques of self assembly. An increase is requested for research to understand how the shapes of molecular building blocks affect the spontaneous assembly into fibers, membranes, and other large-scale structures and to understand the effects of pressure, ionic strength, solvents, and external electric and magnetic fields on the shape and properties of the large-scale structures. This work on self-controlling materials lies at the interface of the physical sciences, molecular biology, and materials engineering. Both natural and synthetic molecules in combination can be used to make new molecular species, and the techniques of molecular self-assembly can be used to create new structures with new properties on the nanoscale. This work will focus on the study of simple structures and phenomena and on the emerging arsenal of tools and techniques such as combinatorial chemistry needed to explore the properties and structures of these new materials.

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.

- **Experimental Program to Stimulate Competitive Research**..... **7,685** **7,679** **7,685**

This activity supports basic research spanning the complete range of activities within the Department in states that have historically received relatively less Federal research funding. The EPSCoR states are Alabama, Alaska, Arkansas, Hawaii, Idaho, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, Nevada, New Mexico, 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 materials sciences, chemical sciences, biological and environmental sciences, high energy and nuclear physics, fusion energy sciences, fossil energy sciences, and energy efficiency and renewable energy sciences.

EPSCoR Distribution of Funds by State

	(dollars in thousands)		
	FY 2001	FY 2002 Estimate	FY 2003 Estimate
Alabama	350	375	375
Alaska[a]	0	0	0
Arkansas	115	65	65
Hawaii[b]	0	0	0
Idaho	107	60	60
Kansas	933	615	615
Kentucky	468	471	471
Louisiana	130	130	130
Maine	0	0	0
Mississippi	652	535	535
Montana	515	465	465
Nebraska	480	300	300
Nevada	614	325	325
New Mexico[b]	0	0	0
North Dakota	0	55	55
Oklahoma	165	65	65
Puerto Rico	450	435	435
South Carolina	1,201	120	120
South Dakota	0	0	0
Vermont	585	585	585
West Virginia	794	525	525
Wyoming	59	65	65
Technical Support	67	400	400
Other	0	2,088 [c]	2,094 [c]
Total	7,685	7,679	7,685

[a] Alaska becomes eligible for funding in FY 2001.

[b] Hawaii and New Mexico become eligible for funding in FY 2002.

[c] Uncommitted funds in FY 2002 and FY 2003 will be competed among all EPSCoR states.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Extension of HB-2 Beam Tube at the High Flux Isotope Reactor**	**1,150**	**0**	**0**

This project is a major item of equipment with a total estimated cost of $5,550,000 that provided beam access for six thermal neutron scattering instruments. The project was completed in FY 2001.

▪ **Neutron Scattering Instrumentation at the High Flux Isotope Reactor**	**0**	**2,000**	**2,000**

Capital equipment funds are provided for new and upgraded instrumentation, such as spectrometers, defractometers, and detectors.

▪ **SPEAR3 Upgrade**	**8,300**	**8,300**	**9,300**

Over the period FY 1999 - FY 2003, the SPEAR3 upgrade (funded in both BES subprograms) is being undertaken at SSRL to provide major improvements to all existing experimental stations served by this synchrotron radiation light source. The technical goals are to increase injection energy from 2.3 GeV to 3 GeV to improve the energy spectrum available to users; decrease beam emittance by a factor of 7 to increase beam brightness; increase operating current from 100 mA to 200 mA to increase beam intensity; and maintain long beam life time (>25 hr). The increased photon flux will greatly improve performance in a variety of applications including powder and thin film diffraction, topographic studies, surface microcontamination studies, x-ray tomographic analysis, x-ray absorption studies, and protein crystallography. The magnets and associated vacuum chambers of the existing SPEAR storage ring will be replaced in order to implement the revised lattice system. All components are housed within the existing buildings. The TEC is $29,000,000; DOE and NIH are equally funding the upgrade with a total Federal cost of $58,000,000. NIH has provided $14,000,000 in FY 1999, $14,000,000 in FY 2000, and $1,000,000 in FY 2001. The funding profile, but not the TEC, of this MIE has been modified based on an Office of Science construction project review, which recommended that some funds be shifted from later years to early years in order to reduce schedule risk by ensuring that critical components are available for installation when scheduled. That recommendation was accepted and is reflected in the current funding profile.

▪ **Advanced Light Source Beamline**	**900**	**975**	**0**

This beamline is a major item of equipment with a total estimated cost of $6,000,000 that will provide capabilities for surface and interfacial science important to geosciences, environmental science, and aqueous corrosion science. It is being funded jointly by the Materials Sciences and Engineering subprogram and the Chemical Sciences, Geosciences, and Energy Biosciences subprogram.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Facilities Operations	**283,467**	**263,865**	**274,118**
▪ **Operation of National User Facilities**	**268,126**	**263,865**	**274,118**

The facilities included in Materials Sciences and Engineering are: Advanced Light Source, Advanced Photon Source, National Synchrotron Light Source, Stanford Synchrotron Radiation Laboratory, High Flux Isotope Reactor, Intense Pulsed Neutron Source, and Manuel Lujan, Jr. Neutron Scattering Center. Research and development in support of the construction of the Spallation Neutron Source is also included. The Combustion Research Facility is funded in the Chemical Sciences, Geosciences, and Energy Biosciences subprogram. The facility operations budget request, presented in a consolidated manner later in this budget, includes operating funds, capital equipment, and Accelerator and Reactor Improvements (AIP) funding under $5,000,000. AIP funding will support additions and modifications to accelerator and reactor facilities that are supported in the Materials Sciences and Engineering 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 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 and Engineering subprogram is provided below.

▪ **High Flux Beam Reactor (HFBR)**	**15,341**	**0**	**0**

The HFBR has been closed. Responsibility for the reactor has been transferred from SC to the Office of Environmental Management (EM) for surveillance and decommissioning. Surveillance will continue until the reactor is fully decommissioned and decontaminated by EM.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Facilities			
Advanced Light Source	35,605	37,009	39,561
Advanced Photon Source	90,314	87,380	91,291
National Synchrotron Light Source	34,720	33,671	35,893
Stanford Synchrotron Radiation Laboratory	21,696	21,357	22,673
High Flux Beam Reactor	15,341	0	0
High Flux Isotope Reactor	37,197	37,872	36,854
Radiochemical Engineering Development Center	6,512	6,606	6,712
Intense Pulsed Neutron Source	13,833	15,826	17,015
Manuel Lujan, Jr. Neutron Scattering Center	9,190	9,044	9,678
Spallation Neutron Source	19,059	15,100	14,441
Total, Facilities	283,467	263,865	274,118

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
SBIR/STTR	**0**	**11,815**	**12,737**

In FY 2001, $9,563,000 and $574,000 were transferred to the SBIR and STTR programs, respectively. The FY 2002 and FY 2003 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.

Total, Materials Sciences and Engineering	**511,608**	**512,522**	**547,883**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Materials Sciences and Engineering Research	
▪ Increase for structure and composition of materials for the design of components for an aberration corrected transmission electron microscope and to enhance remote operations of the electron beam microcharacterization centers	+627
▪ Increase in the area of synthesis and processing for developing a fundamental understanding of nanoscale processes involved in materials deformation and fracture, synthesis of ordered arrays of nanoparticles using patterns techniques and synthesis of nanoparticles of uniform size and shape	+3,905
▪ Increase for neutron and x-ray scattering for new and upgraded instrumentation fabricated both by university and DOE laboratory researchers and for increased support for academic researchers and students. Within this increase, $5,000,000 is provided for instrumentation for the SNS.	+13,766
▪ Increase in condensed matter physics for understanding how properties change or can be improved at the nanoscale and how macromolecules reach their equilibrium configuration and self assemble into larger structures	+3,905
▪ Increase for materials chemistry for research on self assembly of materials at the atomic/molecular level	+1,952
▪ Increase for the Experimental Program to Stimulate Competitive Research to restore funding to FY 2001 levels	+6
▪ Increase in capital equipment funds for the SPEAR3 MIE per approved profile	+1,000
▪ Decrease in capital equipment funds for the ALS Beamline MIE per approved profile	-975
Total, Materials Sciences and Engineering Research	+24,186

	FY 2003 vs. FY 2002 ($000)
Facilities Operations	
▪ Increase for operations for the Advanced Light Source.	+2,552
▪ Increase for operations for the Advanced Photon Source.	+3,911
▪ Increase for operations for the National Synchrotron Light Source.	+2,222
▪ Increase for operations for the Stanford Synchrotron Radiation Laboratory.	+1,316
▪ Decrease for operations for the High-Flux Isotope Reactor because of completion of Cold Guide Hall Extension ($-2,800,000) and increase for HFIR operations ($+1,782,000)	-1,018
▪ Increase for operations for Radiochemical Engineering Development Center	+106
▪ Increase for operations for the Intense Pulsed Neutron Source.	+1,189
▪ Increase for operations for the Manuel Lujan, Jr. Neutron Scattering Center	+634
▪ Decrease in the Spallation Neutron Source research and development funds per FY 2002 project datasheet	-659
Total, Materials Sciences and Engineering Facilities Operations.	+10,253
SBIR/STTR	
▪ Increase in SBIR/STTR funding because of increase in operating expenses	+922
Total Funding Change, Materials Sciences and Engineering	+35,361

Chemical Sciences, Geosciences, and Energy Biosciences

Mission Supporting Goals and Objectives

The Chemical Sciences, Geosciences, and Energy Biosciences subprogram delivers the scientific knowledge and discoveries in the chemical sciences, geosciences, and biosciences that underpin DOE's missions in science, energy, environmental quality, and national security; extends the frontiers of fundamental chemical interactions and molecular processes in order to expand expand the scientific foundations for the development of such advances as efficient combustion systems with reduced emissions of pollutants; new solar photoconversion processes; improves catalysts for cleaner, more efficient, and efficient and cheaper production of fuels and chemicals; and better separations and analytical methods for applications in every DOE mission area; extends the frontiers of energy processes, environmental remediation, and waste management; and geochemistry and geophysics to expand the scientific foundations for contaminant remediation, reservoir definition, and fluid transport to predict repository performance; extends the frontiers of biosciences in order to expand the scientific foundations for the development of renewable biomass resources and the light-driven production of chemical energy via natural photosynthesis; plans, constructs, and operates major scientific user facilities to serve researchers at universities, national laboratories, and industrial laboratories.

The Chemical Sciences, Geosciences, and Energy Biosciences subprogram supports basic research in atomic, molecular and optical science; chemical physics; photochemistry; radiation chemistry; physical chemistry; inorganic chemistry; organic chemistry; analytical chemistry; separation science; heavy element chemistry, geochemistry, geophysics, and physical biosciences. This research seeks to understand chemical reactivity through studies of the interactions of atoms, molecules, and ions with photons and electrons; the making and breaking of chemical bonds in the gas phase, in solutions, at interfaces, and on surfaces; and energy transfer processes within and between molecules. Ultimately, this research leads to the development of such advances as efficient combustion systems with reduced emissions of pollutants; new solar photoconversion processes; improved catalysts for clean and efficient production of fuels and chemicals; and better separations and analytical methods for applications in energy processes, environmental remediation, and waste management. The geosciences activity supports mineral-fluid interactions; rock, fluid, and fracture physical properties; and new methods and techniques for geosciences imaging from the atomic scale to the kilometer scale. The activity contributes to the solution of problems in multiple DOE mission areas, including reactive fluid flow studies to understand contaminant remediation; seismic imaging for reservoir definition; and coupled hydrologic-thermal-mechanical-reactive transport modeling to predict repository performance. The bioscience activity supports basic research in molecular-level studies on solar energy capture through natural photosynthesis; the mechanisms and regulation of carbon fixation and carbon energy storage; the synthesis, degradation, and molecular interconversions of complex hydrocarbons and carbohydrates; and the study of novel biosystems and their potential for materials synthesis, chemical catalysis, and materials synthesized at the nanoscale. This subprogram provides support for chemistry equal to that of the National Science Foundation. It is the Nation's sole support for heavy-element chemistry, and it is Nation's primary support for homogeneous and heterogeneous catalysis, photochemistry, radiation chemistry, separations and analysis, and gas-phase chemical dynamics. This subprogram further provides one third of the federal support for individual investigator research in solid earth sciences.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Chemical Sciences, Geosciences, and Energy Biosciences Research	197,768	197,636	209,319	+11,683	+5.9%
Facilities Operations	5,463	5,377	5,805	+428	+8.0%
SBIR/STTR	0	4,770	5,022	+252	+5.3%
Total, Chemical Sciences, Geosciences, and Energy Biosciences	203,231	207,783	220,146	+12,363	+5.9%

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
Chemical Sciences, Geosciences, and Energy Biosciences Research	**197,768**	**197,636**	**209,319**
▪ **Atomic, Molecular, and Optical (AMO) Science**	**11,428**	**11,815**	**11,815**

This activity supports theory and experiments to understand the properties of and interactions among atoms, molecules, ions, electrons, and photons. Included among the research activities are studies to determine the quantum mechanical description of such properties and interactions; interactions of intense electromagnetic fields with atoms and molecules; development and application of novel x-ray light sources; and ultracold collisions and quantum condensates. This activity also supports the James R. MacDonald Laboratory at Kansas State University, a multi-investigator program and BES collaborative research center devoted to experimental and theoretical studies of collision processes involving highly charged ions.

The knowledge and techniques developed in this activity have wide applicability. Results of this research provide new ways to use photons, electrons, and ions to probe matter in the gas and condensed phases. This has enhanced our ability to understand materials of all kinds and enables the full exploitation of the BES synchrotron light sources, electron beam micro-characterization centers, and neutron scattering facilities. Furthermore, by studying energy transfer within isolated molecules, AMO science provides the very foundation for understanding chemical reactivity, i.e., the process of energy transfer between molecules and ultimately the making and breaking of chemical bonds.

	(dollars in thousands)	
FY 2001	FY 2002	FY 2003

The AMO Science activity is the sole supporter of synchrotron-based AMO science studies in the U.S., which includes ultrashort x-ray pulse generation and utilization at the ALS and APS. This program is also the principal U.S. supporter of research in the properties and interactions of highly charged atomic ions, which are of direct consequence to fusion plasmas.

Research priorities for FY 2003 include the interactions of atoms and molecules with intense electromagnetic fields that are produced by collisions with highly charged ions or short laser pulses; the use of optical fields to control quantum mechanical processes; atomic and molecular interactions at ultracold temperatures and the creation and utilization of quantum condensates, which provides strong linkages between atomic and condensed matter physics at the nanoscale; and the development and application of novel x-ray light sources based on table-top lasers and new utilization of third generation synchrotrons in advance of next-generation BES light sources.

Capital equipment is provided for items including lasers and optical equipment, unique ion sources or traps, position sensitive and solid-state detectors, control and data processing electronics.

	FY 2001	FY 2002	FY 2003
▪ **Chemical Physics Research**...	**27,875**	**33,285**	**33,285**

This activity supports experimental and theoretical investigations of gas phase chemistry and chemistry at surfaces. Gas phase chemistry emphasizes the dynamics and rates of chemical reactions at energies characteristic of combustion with the aim of developing validated theories and computational tools for predicting chemical reaction rates for use in combustion models and experimental tools for validating these models. The study of chemistry at well characterized surfaces and the reactions of metal and metal oxide clusters leads to the development of theories on the molecular origins of surface mediated catalysis.

This activity also has oversight for the Combustion Research Facility (which is budgeted below in Facilities Operations), a multi-investigator facility for the study of combustion science and technology. In-house BES-supported efforts combine theory, modeling, and experiment including diagnostic development, kinetics, and dynamics. 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 gas phase processes. Other activities at the Combustion Research Facility involve BES interactions with the Office of Fossil Energy, the Office of Energy Efficiency and Renewable Energy, and industry.

This activity contributes significantly to DOE missions, since nearly 85 percent of the Nation's energy supply has its origins in combustion and this situation is likely to persist for the foreseeable future. The complexity of combustion -- the interaction of fluid dynamics with hundreds of chemical reactions involving dozens of unstable chemical intermediates -- has provided an impressive challenge to predictive modeling of combustion processes. The chemical physics program supports the development of theories and computational algorithms to predict the rates of chemical reactions at temperatures characteristic of combustion. It supports the development and application of experimental techniques for characterizing gas phase reactions in sufficient detail to develop, test, and validate predictive models of chemical reaction rates. Predicted and measured reaction rates will be

	(dollars in thousands)	
FY 2001	FY 2002	FY 2003

used in models for the design of new combustion devices with maximum energy efficiency and minimum, undesired environmental consequences.

The research in chemical dynamics at surfaces is aimed at developing predictive theories for surface mediated chemistry such as is encountered in industrial catalysis or environmental processes. Surface mediated catalysis reduces the energy demands of industrial chemical processes by bypassing energy barriers to chemical reaction. Surface mediated catalysis is used to remove pollutants from combustion emissions. New catalysts are few; improvements come principally from modification of known catalytic materials. There is no body of organized knowledge such as exists for the field of organic chemistry that can be used to find new catalysts for new or existing processes. The knowledge gained from this research program will guide in the development of a predictive capability for surface chemistry.

Capital equipment is provided for such items as picosecond and femtosecond lasers, high-speed detectors, spectrometers and computational resources.

	FY 2001	FY 2002	FY 2003
▪ **Photochemistry and Radiation Research**	**26,298**	**26,064**	**29,163**

This activity supports fundamental molecular level research on the capture and conversion of energy in the condensed phase. Fundamental research in solar photochemical energy conversion supports organic and inorganic photochemistry, photoinduced electron and energy transfer in the condensed phase, photoelectrochemistry, biophysical aspects of photosynthesis, and biomimetic assemblies for artificial photosynthesis. Fundamental research in radiation chemistry supports chemical effects produced by the absorption of energy from ionizing radiation. The radiation chemistry research encompasses heavy ion radiolysis, models for track structure and radiation damage, characterization of reactive intermediates, radiation yields, and radiation-induced chemistry at interfaces. Accelerator-based electron pulse radiolysis methods are employed in studies of highly reactive transient intermediates, and kinetics and mechanisms of chemical reactions in the liquid phase and at liquid/solid interfaces. This activity supports the Notre Dame Radiation Laboratory, a BES collaborative research center, emphasizing research in radiation chemistry.

Solar photochemical energy conversion is a long-range option for meeting the world’s future energy needs. An alternative to semiconductor photovoltaic cells, the attraction of solar photochemical and photoelectrochemical conversion is that fuels, chemicals and electricity may be produced with minimal environmental pollution and with closed renewable energy cycles. Artificial photosynthesis can be coupled to chemical reactions for generation of fuels such as hydrogen, methane, or complex hydrocarbons found in gasoline. The fundamental concepts devised for highly efficient excited-state charge separation in molecule-based biomimetic assemblies should also be applicable in the future development of molecular optoelectronic devices. A strong interface with EE solar conversion programs exists at NREL, involving shared research, analytical and fabrication facilities, and involving a jointly shared project on dye-sensitized solar cells.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

Radiation chemistry research supports fundamental chemical effects produced by the absorption of energy from ionizing radiation. This research is important for solving problems in environmental waste management and remediation, nuclear energy production, and medical diagnosis and radiation therapy. Fundamental studies on radiation-induced processes complement collocated NERI and EMSP projects.

This activity is the dominant supporter (85%) of solar photochemistry in the U.S., and the sole supporter of radiation chemistry.

An increase is requested in FY 2003 for photochemistry and radiation research for studies of nanoscale structures important to photochemical energy conversion. New opportunities offered by nanoscale science, engineering and technology have enabled studies of artificial and biological self- assembled membranes to isolate and optimally configure chromophores to act as electron-donors and acceptors for efficient charge separation that will allow the desired reaction pathways to be controlled. In addition, studies of quantum dots having unique spectral and electrical properties have the potential to revolutionize direct solar to electrical energy conversion. For FY 2003 research will continue to expand our knowledge of the semiconductor/liquid interface, colloidal semiconductors, and dye-sensitized solar cells; inorganic/organic donor-acceptor molecular assemblies and photocatalytic cycles; biophysical studies of photosynthetic antennae and the reaction center; and radiolytic processes at interfaces, radiolytic intermediates in supercritical fluids, and characterization of excited states by dual pulse radiolysis/photolysis experiments.

Capital equipment is provided for such items as pico- and femtosecond lasers, fast Fourier transform-infrared and Raman spectrometers, and upgrades for electron paramagnetic resonance spectroscopy.

▪ **Molecular Mechanisms of Natural Solar Energy Conversion**	**12,345**	**12,150**	**12,150**

This activity, part of the formerly separate Energy Biosciences subprogram, supports fundamental research to characterize the molecular mechanisms involved in the conversion of solar energy to biomass, biofuels, bioproducts, and other renewable energy resources. Research supported includes the characterization of the energy transfer processes occurring during photosynthesis, the kinetic and catalytic mechanisms of enzymes involved in the synthesis of methane, the biochemical mechanisms involved in the synthesis and degradation of lignocellulosics, and the mechanisms of plant oil production. The approaches used include biophysical, biochemical, and molecular genetic analyses. The goal is to enable the future biotechnological exploitation of these processes and, also, to provide insights and strategies into the design of non-biological processes. This activity also encourages fundamental research in the biological sciences that interfaces with other traditional disciplines in the physical sciences.

▪ **Metabolic Regulation of Energy Production**...........................	**19,508**	**19,224**	**19,224**

This activity, part of the formerly separate Energy Biosciences subprogram, supports fundamental research in regulation of metabolic pathways and the integration of multiple pathways that constitute cellular function. The potential to synthesize an almost limitless variety of energy-rich organic compounds and polymers exists within the genetic diversity of plants and microbes. Understanding and realizing this potential is founded upon characterizing the genetic makeup of the organism and the regulation of these genes by physical and biological parameters. The research goal is to develop a predictive and experimental context for the manipulation and direction of metabolism to accumulate a desired product. Research supported includes the identification and characterization of genes and gene families within the context of metabolic pathways and their regulation by signaling pathways that can impact energy production; this includes understanding the transduction of signals received from physical sources (e.g. light, temperature, solid surfaces) at the interface between the organism and its environment, as well as the transduction of signals received from biological sources (e.g. developmental programs, symbiotic or syntrophic relationships, nutrient availability).

In FY 2003, studies will continue on *Arabidopsis* as a model system for the study of other plant systems with broader utility. Increased emphasis will be placed upon understanding interactions that occur within the nanoscale range; this includes signal reception at biological surfaces and membranes and catalytic and enzyme-substrate recognition and how these molecules transfer within and between cellular components. This new activity constitutes the fundamental biological advances needed to complement the chemical nanoscale catalysis activities. An emerging area will be the development of new imaging tools and methods to examine metabolic and signaling pathways and to visualize cellular architecture, at both the physical-spatial and temporal scale.

	FY 2001	FY 2002	FY 2003
▪ **Catalysis and Chemical Transformation**	**25,464**	**24,779**	**31,333**

This activity supports basic research to understand the chemical aspects of catalysis, both heterogeneous and homogeneous; the chemistry of fossil resources; and the chemistry of the molecules used to create advanced materials. While the "art" of catalysis is widely practiced in industry, the fundamental scientific principles that enable predictability are lacking. This activity seeks to develop these principles to enable rational design of catalysts.

Catalytic transformations impact virtually all of the energy missions of the Department. Catalysts are needed for all of the processes required to convert crude petroleum into a clean burning fuel. This is becoming more and more important as petroleum supplies diminish and demands for cleaner burning fuels increase. Also, the production of virtually every chemical-based consumer product requires catalysts at some point. Catalysts are crucial to energy conservation in creating new, less-energy-demanding routes for the production of basic chemical feedstocks and value-added chemicals. Catalysts are also indispensable for processing and manufacturing fuels that are a primary means of energy storage. Environmental impacts from catalytic science can include minimizing unwanted products from production streams and transforming toxic chemicals into benign ones, such as chloroflurocarbons into environmentally acceptable refrigerants. Research supported by this program also provides the basis and impetus for creating a broad range of new materials, such as mesoporous solids that can act as improved catalysts.

This activity is the Nation's major supporter of catalysis research, and it is the only activity that treats catalysis as a discipline integrating all aspects of homogeneous and heterogeneous catalysis research.

Included within this request are funds to increase x-ray and neutron science activities in the U.S. based on BES reviews of the synchrotron radiation light sources, on discussions within the OSTP Interagency Working Group on Neutron Science, and on three BESAC reviews that addressed the current status of research activities using neutron scattering in the U.S. and strategies needed to take full advantage of the SNS upon its completion. Funding is increased for new and upgraded instrumentation to take advantage of scientific opportunities in the physical sciences and to leverage the multibillion-dollar investment in these facilities. Funds will be competed among both laboratory and academic institutions for multiyear beamline and instrument development projects in the range $5,000,000-15,000,000 each in both homogeneous and heterogeneous catalysis

In FY 2003 research will continue to focus on understanding the unique catalytic properties of metal, as well as mixed metal and oxide particles and their role in catalyzing reactions enabled by nanoscience engineering and technology. Increased emphasis will also be placed on the properties of reactions within nanoscale cavities. Key to these efforts will be studies on the structure, function, and reactivity of metal containing structures both in solution as well as on supports or isolated within three dimensional structures, all within the nanoscale size regime. These activities will focus on understanding the role of nanoscale properties of catalytic materials in controlling chemical reactivity through control of transitions states. Other activities will include the synthesis of discrete nanomaterials created from a controlled assembly of molecular building blocks. Capital equipment is provided for such items as ultrahigh vacuum equipment with various probes of surface structure, Fourier-transform infrared instrumentation, and high-field, solid-state Nuclear Magnetic Resonance (NMR) spectrometers

	FY 2001	FY 2002	FY 2003
▪ **Separations and Analyses**...	**14,393**	**12,967**	**14,407**

This activity supports fundamental research covering a broad spectrum of separation concepts, including membrane processes, extraction under both standard and supercritical conditions, adsorption, chromatography, photodissociation, and complexation. Also supported is work to improve the sensitivity, reliability, and productivity of analytical determinations and to develop entirely new approaches to analysis. This activity is the Nation’s most significant long-term investment in many aspects of separations and analysis, including solvent extraction, ion exchange, and mass spectrometry. The goal of this activity is to obtain a thorough understanding of the basic chemical and physical principles involved in separations systems and analytical tools so that their utility can be realized. Work is closely coupled to the Department’s stewardship responsibility for transuranic chemistry and for the Environmental Management clean-up mission; therefore, separation and analysis of transuranic isotopes and their radioactive decay products are important components of the portfolio.

Knowledge of molecular level processes is required to characterize and treat extremely complex radioactive mixtures and to understand and predict the fate of associated contaminants in the environment. Though the cold war legacy is the most obvious of the Department’s missions, the economic importance of separation science and technology is huge. For example, distillation

	(dollars in thousands)	
FY 2001	FY 2002	FY 2003

processes in the petroleum, chemical, and natural gas industries annually consume the equivalent of 315 million barrels of oil. It has been estimated that separation processes account for more than 5 percent of total national energy consumption. Separations are essential to nearly all operations in the processing industries and are also necessary for many analytical procedures. An analysis is an essential component of every chemical process from manufacture through safety and risk assessment and environmental protection.

Studies in at the nanoscale address molecular transport in nanoscale structures as well as the formation of macroscopic separation systems via self-assembly of nanoscale precursors. Increased funding in FY 2003 is requested for separations and analysis research to address fundamental questions of how individual molecules move on membrane surfaces and within the pores resulting in molecular separations and transformations. This work will build on recent advances in imaging single-molecule interactions and reactions and will expand our knowledge of how molecules interact with pore walls, with one another, and with other molecules to effect separation between molecules.

Capital equipment is provided for such items as computational workstations and inductively coupled plasma torch spectrometers for atomic emission determination.

- **Heavy Element Chemistry** **8,154** **7,637** **8,637**

This activity supports research in actinide and fission product chemistry. Areas of interest include aqueous and non-aqueous coordination chemistry; solution and solid-state speciation and reactivity; measurement of chemical and physical properties; synthesis of actinide-containing materials; chemical properties of the heaviest actinide and transactinide elements; theoretical methods for the prediction of heavy element electronic and molecular structure and reactivity; and the relationship between the actinides, lanthanides, and transition metals.

The heavy element chemistry program, with its genesis in the Manhattan project, has explored the chemical properties of the transuranium and transactinide elements, the latter using techniques developed for isotopes that have half-lives on the order of seconds to tens of seconds. In recent years the emphasis of the program returned to the chemistry of the lighter transuranium elements and fission products, driven by the necessity to identify species found in the waste tanks at the Hanford and Savannah River sites. Knowledge of the molecular speciation of actinide and fission products materials under tank conditions is necessary to treat these complex mixtures. Accidental release of actinide and fission product materials to the environment also requires molecular speciation information in order to predict their fate under environmental conditions. This activity is closely coupled to the BES separations and analysis activity and to the actinide and fission product chemistry efforts in DOE's Environmental Management Science Program.

This activity represents the Nation's only funding for basic research in the chemical and physical principles of actinide and fission product materials. The program is primarily based at the national laboratories because of the special licenses and facilities needed to obtain and safely handle radioactive materials. However, research in heavy element chemistry is supported at universities, and collaborations between university and laboratory programs are encouraged. The training of graduate students and postdoctoral research associates is viewed as an important responsibility of this activity.

Approximately twenty undergraduate students chosen from universities and colleges throughout the U.S. are given introductory lectures in actinide and radiochemistry each summer.

Increased funding in FY 2003 is requested for research in the chemistry of transuranic elements, particularly the role of f-orbital electrons in the coordination chemistry of neptunium, plutonium, americium, and curium. The involvement of the f-orbital electrons in chemical bonding occurs most frequently in the actinide elements and particularly those elements most uniquely associated with the Department of Energy's defense and environmental missions. Experiment combined with theory and modeling will lead to new understanding of chemical bonding in these elements. Experimental studies will include aqueous and non-aqueous high-pressure chemistry and surface chemistry of these elements. In addition, new beamlines at synchrotron light sources capable of handling samples of these heavy elements will permit detailed spectroscopic studies of specimens under a variety of conditions. The study of the bonding in these heavy elements may also provide new insights into organometallic chemistry, beyond that learned from "standard" organometallic chemistry based on transition metals with d-orbital bonding.

Capital equipment is provided for items used to characterize actinide materials (spectrometers, ion chambers, calorimeters, etc.) and equipment for synchrotron light source experiments to safely handle the actinides.

	FY 2001	FY 2002	FY 2003
▪ **Geosciences Research**	**21,419**	**21,262**	**21,262**

The Geosciences activity supports long term basic research in geochemistry and geophysics. Geochemical research focuses on subsurface solution chemistry, mineral-fluid interactions, and isotopic distributions and migration in natural systems. Geophysical research focuses on new approaches to understand physical properties of fluids, rocks and minerals. It seeks fundamental understanding of the physics of wave propagation in complex media ranging from single crystals to the scale of the earth's crust. This activity has pioneered the application of x-ray and neutron scattering to geochemical and geophysical studies.

These studies provide the fundamental science base for new capabilities to locate and monitor oil and gas reservoirs, contaminant migration, and for characterizing disposal sites for energy related wastes. Research also seeks to understand the fundamental geological processes that impact concepts for sequestration of carbon dioxide in subsurface reservoirs. This activity provides the majority of individual investigator basic research funding for the federal government in areas with the greatest impact on unique DOE missions such as high-resolution Earth imaging and low-temperature, low-pressure geochemical processes in the subsurface. This activity provides the basic research component in solid Earth sciences to the DOE's energy resources and environmental quality portfolios.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Chemical Energy and Chemical Engineering**	**12,679**	**10,953**	**10,953**

This activity supports research on electrochemistry, thermophysical and thermochemical properties, and physical and chemical rate processes. Also included is fundamental research in areas critical to understanding the underlying limitations in the performance of electrochemical energy storage and conversion systems including anode, cathode, and electrolyte systems and their interactions with emphasis on improvements in performance and lifetime. The program covers a broad spectrum of research including fundamental studies of composite electrode structures; failure and degradation of active electrode materials; thin film electrodes, electrolytes, and interfaces; and experimental and theoretical aspects of phase equilibria, especially of mixtures, including supercritical phenomena.

Knowledge of bulk behavior of chemicals and mixtures based on molecular properties is required for the design of energy efficient chemical processes in all aspects of plant design across the entire spectrum of industrial activities. The thermophysical and thermochemical properties of molecules provide the basis for developing equations of states and parameters for fluid models that are necessary for the development of engineering designs that maximize the efficiency of all energy production, storage, and consumption devices. These engineering designs are also an essential component of safety and risk assessment and environmental protection.

In the area of energy storage coordination of fundamental and applied research efforts across the government is accomplished by participation in the Interagency Power Working Group. Close coordination with the Battery and Fuel Cell programs in EE-Office of Transportation Technologies is accomplished through joint program meetings, workshops, and strategy sessions.

For FY 2003, there will be continued emphasis on research to expand the ability to control electrode structures on the nanometer scale. Preliminary studies have shown that this has a great impact on the electrochemical efficiency of electrode processes and the rate at which they respond to electrochemical potentials.

Capital equipment is provided for such items as computer work stations and electrochemical apparatus.

▪ **General Plant Projects (GPP)**	**11,524**	**12,170**	**12,210**

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 stewardship responsibilities for these laboratories. Funding of this type is essential for maintaining the productivity and usefulness of the Department-owned facilities and in meeting requirements for safe and reliable facilities operation. Additional GPP funding is included in the Facilities Operations justification in both the Materials Sciences and Engineering subprogram and the Chemical Sciences, Geosciences, and Energy Biosciences subprogram. The total estimated cost of each GPP project will not exceed $5,000,000.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **General Purpose Equipment (GPE)**..	**4,081**	**3,655**	**4,180**

GPE funding is provided for Ames Laboratory, Argonne National Laboratory, and Oak Ridge National Laboratory as part of the Basic Energy Sciences stewardship responsibilities for these laboratories for general purpose equipment that supports multipurpose research. Increased infrastructure funding is requested to maintain, modernize, and upgrade ORNL, ANL, and Ames site and facilities to correct deficiencies due to aging, changing technology, and inadequate past investments.

▪ **SPEAR3 Upgrade**	**1,700**	**700**	**700**

Over the period FY 1999 - FY 2003, the SPEAR3 upgrade (funded in both BES subprograms) is being undertaken at SSRL to provide major improvements to all existing experimental stations served by this synchrotron radiation light source. The technical goals are to increase injection energy from 2.3 GeV to 3 GeV to improve the energy spectrum available to users; decrease beam emittance by a factor of 7 to increase beam brightness; increase operating current from 100 mA to 200 mA to increase beam intensity; and maintain long beam life time (>25 hr). The increased photon flux will greatly improve performance in a variety of applications including powder and thin film diffraction, topographic studies, surface microcontamination studies, x-ray tomographic analysis, x-ray absorption studies, and protein crystallography. The magnets and associated vacuum chambers of the existing SPEAR storage ring will be replaced in order to implement the revised lattice system. All components are housed within the existing buildings. The TEC is $29,000,000; DOE and NIH are equally funding the upgrade with a total Federal cost of $58,000,000. NIH has provided $14,000,000 in FY 1999, $14,000,000 in FY 2000, and $1,000,000 in FY 2001. The funding profile, but not the TEC, of this MIE has been modified based on an Office of Science construction project review, which recommended that some funds be shifted from later years to early years in order to reduce schedule risk by ensuring that critical components are available for installation when scheduled. That recommendation was accepted and is reflected in the current funding profile. **Performance will be measured** by continuing upgrades on the major components of the SPEAR3, maintaining cost and schedule within 10% of baselines. The increased brightness for all experimental stations at SSRL will greatly improve performance in a variety of applications and scientific studies. This subprogram funds the Combustion Research Facility. The x-ray and neutron scattering facility operations, formerly funded in Chemical Sciences, are now funded in the Materials Sciences and Engineering subprogram.

▪ **Advanced Light Source Beamline**	**900**	**975**	**0**

This beamline is a major item of equipment with a total estimated cost of $6,000,000 that will provide capabilities for surface and interfacial science important to geosciences, environmental science, and aqueous corrosion science. It is being funded jointly by the Materials Sciences and Engineering subprogram and the Chemical Sciences, Geosciences, and Energy Biosciences subprogram.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Facility Operations	**5,463**	**5,377**	**5,805**

The facility operations budget request, which includes operating funds, capital equipment, and general plant projects is described in a consolidated manner later in this budget. This subprogram funds the Combustion Research Facility. 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. The x-ray and neutron scattering facility operations, formerly funded in Chemical Sciences, are now funded in the Materials Sciences and Engineering subprogram.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Facilities			
Combustion Research Facility	5,463	5,377	5,805
Total, Facilities	5,463	5,377	5,805

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
SBIR/STTR	**0**	**4,770**	**5,022**

In FY 2001, $4,646,000 and $279,000 were transferred to the SBIR and STTR programs, respectively. The FY 2002 and FY 2003 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.

Total, Chemical Sciences, Geosciences, and Energy Biosciences	**203,231**	**207,783**	**220,146**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Chemical Sciences, Geosciences, and Energy Biosciences Research	
▪ Increase in photochemistry and radiation research for studies of nanoscale structures important to photochemical energy conversion....	+3,099
▪ Increase in catalysis research to understand the role nanoscale properties play in altering and controlling catalytic transformations.	+6,554

	FY 2003 vs. FY 2002 ($000)
▪ Increase for chemical separations and analysis research on how individual molecules move on membrane surfaces and within the pores resulting in molecular separations and transformations.	+1,440
▪ Increase in heavy element chemistry research in the chemistry of transuranic elements, particularly the role of f-orbital electrons in the coordination chemistry of neptunium, plutonium, americium, and curium	+1,000
▪ Increase in General Plant Projects	+40
▪ Increase in General Purpose Equipment	+525
▪ Decrease in capital equipment funding for the ALS Beamline MIE per approved funding profile	-975
Total, Chemical Sciences, Geosciences, and Energy Biosciences Research	+11,683
Facilities Operations	
▪ Increase for operations of the Combustion Research Facility.	+428
Total, Chemical Sciences, Geosciences, and Energy Biosciences Facilities Operations	+428
SBIR/STTR	
▪ Increase SBIR/STTR funding because of increase in operating expenses.	+252
Total Funding Change, Chemical Sciences, Geosciences, and Energy Biosciences	+12,363

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 2001	FY 2002	FY 2003	$ Change	% Change
SNS	258,929	276,300	210,571	-65,729	-23.8%
Project Engineering Design, NSRCs	0	3,000	11,000	+8,000	+266.7%
Project Engineering Design, LCLS	0	0	6,000	+6,000	--
Center for Nanophase Materials Science (ORNL)	0	0	24,000	+24,000	--
Total, Construction	258,929	279,300	251,571	-27,729	-9.9%

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
Construction	**258,929**	**279,300**	**251,571**
Spallation Neutron Source	**258,929**	**276,300**	**210,571**

FY 2003 funding is requested to continue instrument R&D and design, procurement, construction, and installation activities, and to begin system commissioning. The front end will be commissioned, and low-energy linac component installation and commissioning will commence. Other linac and ring components will begin to be delivered and installed in their respective tunnels. Target building construction and equipment installation will continue in concert with each other. Numerous conventional facilities including the klystron, central utilities, and ring service buildings as well as the linac and ring tunnels will be completed. All site utilities will be available to support linac commissioning activities. **Performance will be measured** by continued construction of the SNS, meeting the cost and timetables within 10% of the baseline in the construction project data sheet. Once completed in mid-2006, the SNS will provide beams of neutrons used to probe and understand the physical, chemical, and biological properties of materials at an atomic level, leading to improvements in high technology industries. Additional information follows later in construction project data sheet 99-E-334.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Project Engineering and Design, Nanoscale Science Research Centers	**0**	**3,000**	**11,000**

FY 2003 budget authority is requested to provide Title I and Title II design-only funding for Nanoscale Science Research Centers (NSRCs) at Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, and Sandia National Laboratory to assure project feasibility, define the scope, and provide estimates of construction costs and schedules. NSRCs will provide state-of-the-art facilities for materials nanofabrication and advanced tools for nanocharacterization to the scientific community. Additional information follows later in PED data sheet 02-SC-002.

Project Engineering and Design, Linac Coherent Light Source	**0**	**0**	**6,000**

FY 2003 budget authority is requested to provide Title I and Title II design-only funding for the Linac Coherent Light Source (LCLS) at SLAC to assure project feasibility, define the scope, and provide estimates of construction costs and schedules. The LCLS will provide laser-like radiation in the x-ray region of the spectrum that is 10 orders of magnitude (i.e., a factor of 10,000,000,000) greater in peak power and peak brightness than any existing coherent x-ray light source. Additional information follows later in PED data sheet 03-SC-002.

Nanoscale Science Research Center – The Center for Nanophase Materials Sciences, ORNL	**0**	**0**	**24,000**

FY 2003 funding is requested for the start of construction of the Center for Nanophase Materials Science to be located at Oak Ridge National Laboratory. **Performance will be measured** by meeting the cost and timetables within 10% of the baseline in the construction project data sheet. Additional information follows later in construction project data sheet 03-R-312.

Total, Construction	**258,929**	**279,300**	**251,571**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Construction	
▪ The decrease in funding for the Spallation Neutron Source represents the scheduled ramp down of activities.	-65,729
▪ Increase in Project Engineering and Design for Nanoscale Science Research Centers at ORNL, LBNL, and SNL.	+8,000
▪ Increase in funding for the start of construction of the Center for Nanophase Materials Science to be located at ORNL.	+24,000
▪ Increase in funding for Project Engineering Design related to design-only activities for the Linac Coherent Light Source (LCLS).	+6,000
Total Funding Change, Construction	-27,729

Major User Facilities

Mission Supporting Goals and Objectives

The BES scientific user facilities provide experimental capabilities that are beyond the scope of those found in laboratories of individual investigators. Synchrotron radiation light sources, high-flux neutron sources, electron beam microcharacterization centers, and other specialized facilities enable scientists to carry out experiments that could not be done elsewhere. These facilities are part of the Department's system of scientific user facilities, the largest of its kind in the world. A description of each facility is provided in the "Site Descriptions" section. Any unusual or nonrecurring aspects of funding are described in the following section "Detailed Program Justification."

The facilities are planned in collaboration with the scientific community and are constructed and operated by BES for support of forefront research in areas important to BES activities and also in areas that extend beyond the scope of BES activities such as structural biology, medical imaging, and micro machining. These facilities are used by researchers in materials sciences, chemical sciences, earth and geosciences, environmental sciences, structural biology, superconductor technology, and medical research and technology development. The facilities are open to all qualified scientists from academia, industry, and the federal laboratory system whose intention is to publish in the open literature. The funding schedule includes only those facilities that have operating budgets for personnel, utilities, and maintenance.

Funding Schedule

Funding for the operation of these facilities is provided in the Materials Sciences and Engineering and the Chemical Sciences, Geosciences, and Energy Biosciences subprograms.

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Advanced Light Source	35,605	37,009	39,561	+2,552	+6.9%
Advanced Photon Source	90,314	87,380	91,291	+3,911	+4.5%
National Synchrotron Light Source	34,720	33,671	35,893	+2,222	+6.6%
Stanford Synchrotron Radiation Laboratory	21,696	21,357	22,673	+1,316	+6.2%
High Flux Beam Reactor	15,341	0	0	0	--
High Flux Isotope Reactor	37,197	37,872	36,854	-1,018	-2.7%
Radiochemical Engineering Development Center	6,512	6,606	6,712	+106	+1.6%
Intense Pulsed Neutron Source	13,833	15,826	17,015	+1,189	+7.5%
Manuel Lujan, Jr. Neutron Scattering Center	9,190	9,044	9,678	+634	+7.0%
Spallation Neutron Source	19,059	15,100	14,441	-659	-4.4%
Combustion Research Facility	5,463	5,377	5,805	+428	+8.0%
Total, Major User Facilities	288,930	269,242	279,923	+10,681	+4.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Major User Facilities	**288,930**	**269,242**	**279,923**
▪ Advanced Light Source at Lawrence Berkeley National Laboratory.	35,605	37,009	39,561
▪ Advanced Photon Source at Argonne National Laboratory.	90,314	87,380	91,291
▪ National Synchrotron Light Source at Brookhaven National Laboratory.	34,720	33,671	35,893
▪ Stanford Synchrotron Radiation Laboratory at Stanford Linear Accelerator Center.	21,696	21,357	22,673
▪ High Flux Beam Reactor at Brookhaven National Laboratory. On November 16, 1999, Secretary Richardson announced the permanent closure of the reactor. Responsibility has been transferred from SC to the Office of Environmental Management for surveillance and decommissioning.	15,341	0	0
▪ High Flux Isotope Reactor at Oak Ridge National Laboratory.	37,197	37,872	36,854
▪ Radiochemical Engineering Development Center (REDC) at Oak Ridge National Laboratory.	6,512	6,606	6,712
▪ Intense Pulsed Neutron Source at Argonne National Laboratory.	13,833	15,826	17,015
▪ Manuel Lujan, Jr. Neutron Scattering Center at Los Alamos National Laboratory.	9,190	9,044	9,678
▪ Spallation Neutron Source at Oak Ridge National Laboratory.	19,059	15,100	14,441
▪ Combustion Research Facility at Sandia National Laboratories/California.	5,463	5,377	5,805
Total, Major User Facilities	288,930	269,242	279,923

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

	FY 2001	FY 2002	FY 2003	$ Change	% Change
	(dollars in thousands)				
General Plant Projects	11,874	12,518	12,570	+52	+0.4%
Accelerator Improvement Projects	11,935	11,577	9,067	-2,510	-21.7%
Capital Equipment	62,165	62,235	76,249	+14,014	+22.5%
Total, Capital Operating Expenses	85,974	86,330	97,886	+11,556	+13.4%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2001	FY 2002	FY 2003	Unapprop-riated Balances
99-E-334 Spallation Neutron Source, ORNL	1,192,700	201,400	258,929	276,300	210,571	245,500
02-SC-002 PED, Nanoscale Science Research Centers	15,000 [a]	0	0	3,000	11,000	1,000
03-SC-002, PED, Stanford Linear Accelerator Center	33,500 [b]	0	0	0	6,000	27,500
03-R-312, ORNL, Center for Nanophase Material Sciences	64,250	0	0	0	24,000	40,250
Total, Construction		201,400	258,929	279,300	251,571	314,250

[a] The full Total Estimated Cost (design and construction) ranges between $160,000,000 and $235,000,000. This estimate is based on conceptual data and should not be construed as a project baseline.

[b] The full TEC Projection (design and construction) ranges between $165,000,000 and $225,000,000. This is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2001	FY 2002	FY 2003 Request	Accept-ance Date
HB-2 Beam Tube Extension at HFIR - ORNL	5,550	4,400	1,150	0	0	FY 2001
SPEAR3 Upgrade	29,000[a]	0	10,000	9,000	10,000	FY 2003
ALS Beamline	6,000	2,250	1,800	1,950	0	FY 2003
Total, Major Items of Equipment		6,650	12,950	10,950	10,000	

[a] DOE portion only; total estimated Federal cost, including NIH funding (beginning in FY 1999), is $58,000,000.

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

(Changes from FY 2002 Congressional Budget Request are denoted with a vertical line in the left margin.)

Significant Changes

Clarifying language has been added to Sections 2 and 3 with respect to scientific instruments that are related to, but not a part of, the SNS Project.

Estimate of related Annual Funding Requirements has been updated in Section 7.

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 1999 Budget Request (Preliminary Estimate)	1Q 1999	4Q 2003	3Q 2000	4Q 2005	1,138,800	1,332,800
FY 2000 Budget Request	1Q 1999	4Q 2003	3Q 2000	1Q 2006	1,159,500	1,360,000
FY 2001 Budget Request	1Q 1999	4Q 2003	3Q 2000	3Q 2006	1,220,000	1,440,000
FY 2001 Budget Request (*Amended*)	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700
FY 2002 Budget Request	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700
FY 2003 Budget Request (*Current Estimate*)	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700

2. Financial Schedule [1]

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
1999	101,400	101,400	37,140
2000	100,000	100,000	105,542
2001	258,929	258,929	170,453
2002	276,300	276,300	287,732
2003	210,571	210,571	301,304
2004	124,600	124,600	159,752
2005	79,800	79,800	83,146
2006	41,100	41,100	47,631

[1] In FY 2001, two grants were awarded to universities for research covering the design, fabrication and installation of instruments for neutron scattering. Both awards were made based on competitive peer review under 10CFR Part 605, Financial Assistance Program. Both instruments will be located at the SNS. These awards follow the advice of the Basic Energy Sciences Advisory Committee, that the Department should "expand the university base for neutron scattering. The only way to build the user base required to be internationally competitive is to enhance the participation from academic institutions. An immediate injection of funds to support the exploitation of pulsed neutron sources for science by the U.S. academic community is needed." Several universities participate in these grants, including MIT, University of California, University of Delaware, University of Colorado, University of Utah, Johns Hopkins, University of New Mexico, and Syracuse University. Pennsylvania State University submitted an application on April 12, 2001. After peer review the award to Pennsylvania State University was made for 5 years, starting August 15, 2001, and ending August 14, 2006, for a total of $12,824,168 of operating funds for an instrument for research in inelastic neutron scattering, quantum liquids, magnetism, environmental chemistry, polymer dynamics, and lubrication. This instrument will be owned by Pennsylvania State University.

The California Institute of Technology submitted an application on June 11, 2001. After peer review, the award to California Institute of Technology was made for 5 years, starting September 15, 2001, and ending September 14, 2006, for a total of $11,579,000 of operating funds for an instrument for research in lattice dynamics, magnetic dynamics, chemical physics, and characterization of novel materials. This instrument will be owned by California Institute of Technology.

In addition to the two above identified instruments, the Basic Energy Sciences program will provide $5,000,000 of Materials Sciences and Engineering subprogram funding in FY 2003 to continue the development of instrumentation to exploit the scientific potential of the SNS facility. These instruments will be built by individual DOE laboratories or consortia of DOE laboratories in collaboration with the SNS based on scientific merit and importance to users from universities, industries, and government laboratories. The instruments will be operated for users by the SNS based on applications for experiments selected competitively by the peer review procedures established for access to the SNS. See further discussion in Materials Sciences and Engineering subprogram under X-ray and Neutron Scattering.

3. Project Description, Justification and Scope [1]

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, when in full operation, will be used by 1,000-2,000 scientists and engineers each year and that it will meet the national need for neutron science capabilities well into the 21st Century. Neutrons enable scientists studying the physical, chemical, and biological properties of materials to determine how atoms and molecules are arranged and how they move. This is the microscopic basis for understanding and developing materials of technological significance to support information technology, transportation, pharmaceuticals, magnetic, and many other economically important areas.

The importance of neutron science for fundamental discoveries and technological development is universally acknowledged. The scientific justification and need for a new neutron source and instrumentation in the U.S. have been thoroughly established by numerous studies by the scientific community since the 1970s. These include the 1984 National Research Council study *Major Facilities for Materials Research and Related Disciplines* (the Seitz-Eastman Report), which recommended the immediate start of the design of both a steady-state source and an accelerator-based pulsed spallation source. More recently, the 1993 DOE Basic Energy Sciences Advisory Committee (BESAC) report *Neutron Sources for America's Future* (the Kohn Panel Report) again included construction of a new pulsed spallation source with SNS capabilities among its highest priorities. This conclusion was even more strongly reaffirmed by the 1996 BESAC Report (the Russell Panel Report), which recommended the construction of a 1 megawatt (MW) spallation source that could be upgraded to significantly higher powers in the future.

Neutrons are a unique and increasingly indispensable scientific tool. Over the past decade, they have made invaluable contributions to the understanding and development of many classes of new materials, from high temperature superconductors to fullerenes, a new form of carbon. In addition to creating the new scientific knowledge upon which unforeseen breakthroughs will be based, neutron science is at the core of many technologies that currently improve the health of our citizenry and the safety and effectiveness of our industrial materials.

The information that neutrons provide has wide impacts. For example, chemical companies use neutrons to make better fibers, plastics, and catalysts; drug companies use neutrons to design drugs with higher potency and fewer side effects; and automobile manufacturers use the penetrating power of neutrons to understand how to cast and forge gears and brake discs in order to make cars run better and more safely. Furthermore, research on magnetism using neutrons has led to higher strength magnets for more efficient electric generators and motors and to better magnetic materials for magnetic recording tapes and computer hard drives.

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[1] As part of the development of Oak Ridge National Laboratory, other buildings may be located on Chestnut Ridge, which is the site of the SNS and is located just across Bethel Valley Road from improvements planned for the main ORNL campus. For example, the Center for Nanophase Materials Sciences (CNMS) will be located on Chestnut Ridge, because research activities at the CNMS will integrate nanoscale science research with neutron science; synthesis; and theory, modeling, and simulation. The CNMS will be adjacent to the SNS Laboratory – Office Building and will be connected to it by a walkway. See construction project datasheet 03-R-312 for further information on the CNMS.

Based on the recommendations of the scientific community obtained via the Russell Panel Report, the SNS is required to operate at an average power on target of at least 1 megawatt (MW); although the designers had aimed for 2 MW, current projections fall between 1 to 2 MW. At this power level, the SNS will be the most powerful spallation source in the world-many times that of ISIS at the Rutherford Laboratory in the United Kingdom. Furthermore, the SNS is specifically designed to take advantage of improvements in technology, new technologies, and additional hardware to permit upgrades to substantially higher power as they become available. Thus, the SNS will be the nation's premiere neutron facility for many decades.

The importance of high power, and consequently high neutron flux (i.e., high neutron intensity), cannot be overstated. The properties of neutrons that make them an ideal probe of matter also require that they be generated with high flux. (Neutrons are particles with the mass of the proton, with a magnetic moment, and with no electrical charge.) Neutrons interact with nuclei and magnetic fields; both interactions are extremely weak, but they are known with great accuracy. Because they have spin, neutrons have a magnetic moment and can be used to study magnetic structure and magnetic properties of materials. Because they weakly interact with materials, neutrons are highly penetrating and can be used to study bulk phase samples, highly complex samples, and samples confined in thick-walled metal containers. Because their interactions are weak and known with great accuracy, neutron scattering is far more easily interpreted than either photon scattering or electron scattering. However, the relatively low flux of existing neutron sources and the small fraction of neutrons that get scattered by most materials mean that most measurements are limited by the source intensity.

The pursuit of high-flux neutron sources is more than just a desire to perform experiments faster, although that, of course, is an obvious benefit. High flux enables broad classes of experiments that cannot be done with low-flux sources. For example, high flux enables studies of small samples, complex molecules and structures, time-dependent phenomena, and very weak interactions. Put most simply, high flux enables studies of complex materials in real time and in all disciplines--physics, chemistry, materials science, geosciences, and biological and medical sciences. Oak Ridge National Laboratory has extensive research efforts in all of these areas.

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 approximately 1 billion electron volts (GeV) energy in a linear accelerator (linac); the hydrogen ion beam is injected into an accumulator ring through a stripper foil, which strips the electrons off of the hydrogen ions to produce a proton beam; the proton beam is collected and bunched into short pulses in the accumulator ring; and, finally, the proton beam is injected into a heavy metal target at a frequency of up to 60 Hz. The intense proton bursts striking the target produce pulsed neutron beams by the spallation process. The high-energy neutrons so produced are moderated (i.e., slowed down) to reduce their energies, typically by using thermal or cold moderators. The moderated neutron beams are then used for neutron scattering experiments. Specially designed scientific instruments use these pulsed neutron beams for a wide variety of investigations.

The primary objectives in the design of the site and buildings for the SNS are to provide optimal facilities for the DOE and the scientific community for neutron scattering well into the 21st Century and to address the mix of needs associated with the user community, the operations staff, security, and safety.

A research and development (R&D) 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; accumulator ring; target station with moderators; beam transport systems; and initial experimental equipment necessary to place the SNS in operation) and attendant conventional facilities. As the project design and construction progresses, value engineering analyses and R&D define changes that are applied to the technical baseline to maximize the initial scientific capability of the SNS within the currently established cost and schedule. Thus the SNS project will be considered complete when all capital facilities necessary to achieve the initial baseline goals have been installed and certified to operate safely and properly. In addition, to the extent possible within the total project cost, provisions will be made to facilitate a progression of future improvements and upgrades aimed at keeping SNS at the forefront of neutron scattering science throughout its operating lifetime. Indeed, the current design contains a number of enhancements (e.g. superconducting radiofrequency acceleration, best-in-class instruments, more instrument stations, and higher energy ring) that provide higher performance than the conceptual design that was the basis of initial project approval.

The scientific user community has advised the DOE Office of Basic Energy Sciences that the SNS should keep pace with developments in scientific instruments. Since the average cost for a state-of-the-art instrument has roughly doubled in recent years, SNS has reduced the number of instruments provided within the project TEC. Although this translates into an initial suite of five rather than the ten instruments originally envisioned, the cumulative scientific capability of the SNS has actually increased more than ten-fold. In order to optimize the overall project installation sequence and early experimental operations, three of these instruments will be installed as part of the project; the other two will be completed, with installation occurring during initial low power operations. As with all scientific user facilities such as SNS, additional and even more capable instruments will be installed over the course of its operating lifetime. Many of these future instruments will be provided by other entities, such as the National Science Foundation, other countries, as well as other DOE programs.

The SNS project made significant progress in FY 2001 towards scheduled milestones. R&D supporting technical component design is now over 90% complete. Project-wide, design work is about 70% complete, with conventional facility Title II design nearly 100% complete. Site preparation was completed, and construction began on the front end and target buildings, the linac tunnel, as well as a number of support buildings and utility systems. A number of procurements for materials and technical components were awarded, with generally favorable cost results, and delivery of some items to Oak Ridge began. Definitive plans for equipment delivery and installation and for handoff of technical systems to Oak Ridge for commissioning activities were developed.

FY 2002 budget authority will be used to continue R&D, design, procurement, and construction activities, and to begin component installation. Essentially all R&D supporting construction of the SNS will be completed, with instrument R&D continuing. Title II design will be completed on the linac, and will continue on the ring, target, and instrument systems. The completed front end ion source and portions of the drift tube linac will be delivered to the site to begin their installation. Other system components for the accelerator, ring, target, and instruments will continue to be manufactured. Work on conventional facilities will continue, with some reaching completion and being turned over for equipment installation, such as the front end building, and portions of the klystron building and linac tunnel. Construction work will begin on the ring tunnel.

FY 2003 budget authority is requested to continue instrument R&D and design, procurement, construction, and installation activities, and to begin system commissioning. The front end will be commissioned, and the drift tube linac will be installed and commissioning begun. Installation of other linac components will proceed and installation of ring components will begin. Target building construction and equipment installation will continue in concert with each other. Numerous conventional facilities, including the klystron, central utilities, and ring service buildings as well as the linac and ring tunnels, will be completed. All site utilities will be available to support linac commissioning activities.

4. Details of Cost Estimate

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design and Management Costs		
Engineering, design and inspection at approximately 22% of construction costs	159,500	179,400
Construction management at approximately 2% of construction costs	14,000	20,400
Project management at approximately 14% of construction costs	104,700	121,800
Land and land rights	0	0
Construction Costs		
Improvements to land (grading, paving, landscaping, and sidewalks)	31,500	28,300
Buildings	181,600	173,600
Utilities (electrical, water, steam, and sewer lines)	20,900	25,100
Technical Components	505,500	441,400
Standard Equipment	17,500	1,900
Major computer items	5,500	5,300
Design and project liaison, testing, checkout and acceptance	31,000	16,600
Subtotal	1,071,700	1,013,800
Contingencies at approximately 11% of above costs[1]	121,000	178,900
Total Line Item Cost	1,192,700	1,192,700
Less: Non-Agency Contribution	0	0
Total, Line Item Costs (TEC)	1,192,700	1,192,700

[1] The contingency, expressed as a percentage of the remaining effort to complete the line item project, is approximately 20%.

5. Method of Performance

The SNS project is being carried out by a partnership of six DOE national laboratories, led by Oak Ridge National Laboratory, as the prime contractor to DOE. The other five laboratories are Argonne, Brookhaven, Lawrence Berkeley, Los Alamos National Laboratories and Thomas Jefferson National Accelerator Facility. Each laboratory is assigned responsibility for accomplishing a well defined portion of the project's scope that takes advantage of their technical strengths: Argonne - Instruments; Brookhaven - Accumulator Ring; Lawrence Berkeley - Front End; Los Alamos – Normal conducting linac and RF power systems; TJNAF – Superconducting Linac; Oak Ridge - Target. Project execution is the responsibility of the SNS Project Director with the support of a central SNS Project Office at ORNL, which provides overall project management, systems integration, ES&H, quality assurance, and commissioning support. The SNS Project Director has authority for directing the efforts at all six partner laboratories and exercises financial control over all project activities. ORNL has subcontracted to an Industry Team that consists of an Architect-Engineer for the conventional facilities design and a Construction Manager for construction installation, equipment procurement, testing and commissioning support. Procurements by all six laboratories will be accomplished, to the extent feasible, by fixed price subcontracts awarded on the basis of competitive bidding.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 2001	FY 2002	FY 2003	Outyears	Total
Project Cost						
Facility Cost [1]						
Line Item TEC	142,682	170,453	287,732	301,304	290,529	1,192,700
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	142,682	170,453	287,732	301,304	290,529	1,192,700
Other project costs						
R&D necessary to complete project [2]	60,356	13,019	4,323	2,328	4,526	84,552
Conceptual design cost [3]	14,397	0	0	0	0	14,397
Decontamination & Decommissioning (D&D)	0	0	0	0	0	0
NEPA Documentation costs [4]	1,948	0	0	0	0	1,948
Other project-related costs [5]	3,824	6,707	11,421	12,553	82,495	117,000
Capital equipment not related construction [6]	664	183	100	100	56	1,103
Total, Other project costs	81,189	19,909	15,844	14,981	87,077	219,000
Total project cost (TPC)	223,871	190,362	303,576	316,285	377,606	1,411,700

[1] 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 $1,192,700,000.

[2] A research and development program at an estimated cost of $84,552,000 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.

[3] Costs of $14,397,000 are included for conceptual design and for preparation of the conceptual design documentation prior to the start of Title I design in FY 1999.

[4] Estimated costs of $1,948,000 are included to complete the Environmental Impact Statement.

[5] Estimated costs of $117,000,000 are included to cover pre-operations costs.

[6] Estimated costs of $1,103,000 to provide test facilities and other capital equipment to support the R&D program.

7. Related Annual Funding Requirements

	(FY 2007 dollars in thousands) [1] Current Estimate	Previous Estimate
Facility operating costs	45,700	21,300
Facility maintenance and repair costs	24,800	25,300
Programmatic operating expenses directly related to the facility	40,000	22,500
Capital equipment not related to construction but related to the programmatic effort in the facility	11,800	2,100
GPP or other construction related to the programmatic effort in the facility	1,000	1,000
Utility costs	19,400	30,400
Accelerator Improvement Modifications (AIMs)	7,300	4,100
Total related annual funding (4Q FY 2006 will begin operations)	150,000	106,700

During conceptual design of the SNS project, the annual funding requirements were initially estimated based on the cost of operating similar facilities (e.g. ISIS and the Advanced Photon Source) at $106,700,000. The operating parameters, technical capabilities, and science program are now better defined and the key members of the ORNL team that will operate SNS are now in place. Based on these factors, the SNS Project developed a new estimate of annual operating costs, which was independently reviewed by the Department, and provides the basis of the current estimate indicated above. FY 2007 will be the first full year of operations and this estimate is generally representative of the early period of SNS operations. By the time SNS is fully instrumented and the facility is upgraded to reach its full scientific potential, the annual funding requirements will increase by an additional 10-15 percent.

8. Design and Construction of Federal Facilities

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

[1] The previous estimate was in FY 2006 dollars.

02-SC-002 - Project Engineering Design (PED), Various Locations

(Changes from the FY 2002 Congressional Budget Request are denoted with a vertical line in the left margin.)

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete	
FY 2002 Budget Request (Preliminary Estimate)	2Q 2002	3Q 2004	N/A	N/A	14,000
FY 2003 Budget Request (Current Estimate)	2Q 2002	3Q 2003	N/A	N/A	15,000 [a]

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	3,000	3,000	3,000
2003	11,000	11,000	11,000
2004	1,000	1,000	1,000

3. Project Description, Justification and Scope

This PED request provides for Title I and Title II Architect-Engineering (A-E) services for Basic Energy Sciences (BES) projects related to the establishment of user centers for nanoscale science, engineering, and technology research. These funds allow designated projects to proceed from conceptual design into preliminary design (Title I) and definitive design (Title II). The design effort will be sufficient to assure project feasibility, define the scope, provide detailed estimates of construction costs based on the approved design and working drawings and specifications, and provide construction schedules including procurements. The design effort will ensure that construction can physically start or long-lead procurement items can be procured in the fiscal year in which Title III construction activities are funded.

Updated FY 2003 PED design projects are described below. Some changes may occur due to continuing conceptual design studies or developments prior to enactment of an appropriation. These changes will be reflected in subsequent years. Construction funding for one of the FY 2002 subprojects is also separately requested in FY 2003.

[a] The full Total Estimated Cost (design and construction) ranges between $239,000,000 - $329,000,000. This estimate was based on conceptual data and should not be construed as a project baseline. Based on the results of peer review, the total design cost is changed to $15,000,000. The full Total Estimated Cost for one project, subproject 02-04, currently proposed for construction is identified in the FY 2003 construction datasheet.

Nanoscale Science Research Centers (NSRCs)

To support research in nanoscale science, engineering, and technology, the U.S. has constructed outstanding facilities for *characterization and analysis* of materials at the nanoscale. Most of these world-class facilities are owned and operated by BES. They include, for example, the synchrotron radiation light source facilities, the neutron scattering facilities, and the electron beam microscope centers. However, world-class facilities that are widely available to the scientific research community for nanoscale *synthesis, processing, and fabrication* do not exist. NSRCs are intended to fill that need. NSRCs will serve the Nation's researchers and complement university and industrial capabilities in the tradition of the BES user facilities and collaborative research centers. Through the establishment of NSRCs affiliated with existing major user facilities, BES will provide state-of-the-art equipment for materials synthesis, processing, and fabrication at the nanoscale in the same location as facilities for characterization and analysis. NSRCs will build on the existing research and facility strengths of the host institutions in materials science and chemistry research and in x-ray and neutron scattering. This powerful combination of colocated fabrication and characterization tools will provide an invaluable resource for the Nation's researchers.

In summary, the purposes of NSRCs are to:

- provide state-of-the-art nanofabrication and characterization equipment to in-house and visiting researchers,
- advance the fundamental understanding and control of materials at the nanoscale,
- provide an environment to support research of a scope, complexity, and disciplinary breadth not possible under traditional individual investigator or small group efforts,
- provide a formal mechanism for both short- and long-term collaborations and partnerships among DOE laboratory, academic, and industrial researchers,
- provide training for graduate students and postdoctoral associates in interdisciplinary nanoscale science, engineering, and technology research,
- provide the foundation for the development of nanotechnologies important to the Department.

Centers have been proposed by: Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), and a consortium of Los Alamos National Laboratory (LANL) and Sandia National Laboratory (SNL). Based on peer review of the Center proposals, PED funding is being provided in FY 2002 and requested in FY 2003 for LBNL, ORNL, and LANL/SNL. Construction funding is also requested for ORNL in FY 2003.

FY 2002 Proposed Design Projects

FY 02-01: Center for Nanoscale Materials – Argonne National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
2Q 2002	2Q 2003	3Q 2003	N/A	2,000	45,000-65,000

Fiscal Year	Appropriations	Obligations	Costs
2002	0 [b]	0[b]	0[b]
2003	0 [b]	0[b]	0[b]

The Center for Nanoscale Materials (CNM) at ANL will consist of conventional facilities, fabrication facilities, characterization instruments, computational capabilities, and beamlines at the Advanced Photon Source (APS). The CNM will be attached to the APS at a location not occupied by one of the standard Laboratory-Office Modules that serve the majority of the APS sectors. Most specifications of the conventional facilities design for CNM will be intimately connected to the specifications of the technical systems. Towards this end, effort will be dedicated to optimizing both the conventional facilities and the technical facilities, looking for value engineering opportunities. The Center at Argonne will require approximately 10,000 square feet of class 1,000 clean room space for nanofabrication and characterization equipment. This facility will also require general purpose chemistry/biology laboratories (7,000 square feet) and electronic and physical measurement laboratories (3,000 square feet). To house the CNM staff, university collaborators (post docs, visiting students and faculty), and industry collaborators, approximately 16,000 square feet for offices and meeting rooms will be provided. The CNM is being coordinated with a State of Illinois effort. Based on the results of the FY 2001 peer review of the CNM, PED funding is not planned for FY 2002 or requested for this effort in FY 2003.

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[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

[b] The FY 2002 Request included funding of $1,000,000 in FY 2002 and FY 2003 for this project. Based on results of peer review, funding is not planned for FY 2002 or requested for this project in FY 2003.

02-02: The Molecular Foundry – Lawrence Berkeley National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
2Q 2002	3Q 2003	4Q 2003	N/A	8,300	55,000 – 75,000

Fiscal Year	Appropriations	Obligations	Costs
2002	500[b]	500[b]	500[b]
2003	6,800[b]	6,800[b]	6,800[b]
2004	1,000	1,000	1,000

The Molecular Foundry will be a two to four story high structure adjacent to the Advanced Light Source, with a total gross area of approximately 90,000 square feet and net usable area of approximately 53,000 square feet. Space in the new facility will support studies in nanostructures by providing offices and laboratories for materials science, physics, chemistry, biology, molecular biology and engineering, as well as approximately 6,000 square feet of high bay area. The building will be a state-of-the art facility for the design, modeling, synthesis, processing, and fabrication of novel molecules and nanoscale materials and their characterization. State-of-the-art equipment will support this research; e.g.: cleanroom, class 10-100; controlled environment rooms; scanning tunneling microscopes; atomic force microscopes; transmission electron microscope; fluorescence microscopes; mass spectrometers; DNA synthesizer, sequencer; nuclear magnetic resonance spectrometer; ultrahigh vacuum scanning-probe microscopes; photo, uv, and e-beam lithography equipment; peptide synthesizer; advanced preparative and analytical chromatographic equipment; and cell culture facilities. New and existing beamlines at the ALS, not part of this PED activity, will support efforts at the Molecular Foundry.

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

[b] The FY 2002 Request included $1,000,000 for FY 2002 and $2,000,000 for FY 2003. Based on the results of peer review, current funding plan is $500,000 for FY 2002, $6,800,000 for FY 2003, and $1,000,000 for FY 2004.

02-03: Center for Functional Nanomaterials – Brookhaven National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
2Q 2002	3Q 2003	4Q 2003	N/A	3,000	45,000-65,000

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	0 [b]	0 [b]	0 [b]
2003	0 [b]	0 [b]	0 [b]

The Center for Functional Nanomaterials will include class 10 clean rooms, general laboratories, wet and dry laboratories for sample preparation, fabrication, and analysis. Included will be the equipment necessary to explore, manipulate, and fabricate nanoscale materials and structures. Also included are individual offices and landscape office areas, seminar area, transient user space for visiting collaborators with access to computer terminals, conference areas on both floors, and vending/lounge areas. In addition it will include circulation/ancillary space, including mechanical equipment area, toilet rooms, corridors, and other support spaces. Equipment procurement for the project will include equipment needed for laboratory and fabrication facilities for e-beam lithography, transmission electron microscopy, scanning probes and surface characterization, material synthesis and fabrication, and spectroscopy. The building will incorporate human factors into its design to encourage peer interactions and collaborative interchange by BNL staff and research teams from collaborating institutions. In addition to flexible office and laboratory space it will provide “interaction areas”, a seminar room and a lunch room for informal discussions. This design approach is considered state-of-the-art in research facility design as it leverages opportunities for the free and open exchange of ideas essential to creative research processes. Based on the results of the FY 2001 peer review of the Center for Functional Nanomaterials, PED funding is not planned for FY 2002 or requested for this project in FY 2003.

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

[b] The FY 2002 Request included $1,000,000 in FY 2002 and $2,000,000 in FY 2003 for this project. Based on results of peer review, funding is not planned for FY 2002 or requested for this project in FY 2003.

02-04: Center for Nanophase Materials Sciences – Oak Ridge National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
2Q 2002 [b]	3Q 2003 [b]	4Q 2003 [b]	N/A	2,500 [b]	64,000

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	1,500 [b]	1,500 [b]	1,500 [b]
2003	1,000 [b]	1,000 [b]	1,000 [b]

A major focus of the Center for Nanophase Materials Sciences (CNMS) will be the application of neutron scattering for characterization of nanophase materials. In this area, CNMS will be a world leader. With the construction of the new Spallation Neutron Source (SNS) and the upgraded High Flux Isotope Reactor (HFIR), it is essential that the U.S.-based neutron science R&D community grow to the levels found elsewhere in the world and assume a scientific leadership role. Neutron scattering provides unique information about both atomic-scale structure and the dynamics of a wide variety of condensed matter systems including polymers, macromolecular systems, magnetic and superconducting materials, and chemically complex materials, particularly oxides and hydrogen-containing structures. Consequently, the intense neutron beams at HFIR and SNS will make, for the first time, broad classes of related nanoscale phenomena accessible to fundamental study.

The CNMS will occupy an 80,000 sq.ft. building containing wet and dry materials synthesis and characterization laboratories; clean rooms and materials imaging, manipulation, and integration facilities in a nanofabrication research laboratory; computer-access laboratories for nanomaterials theory and modeling; and office space for staff and visitors. The CNMS facility will consist of a multi-story building for materials synthesis and characterization contiguous with a single-story structure for nanofabrication having Class 100, Class 1,000, and Class 10,000 clean areas. The latter portion of the facility will be built using a construction approach that will meet low electromagnetic field, vibration, and acoustic noise requirements for special nanofabrication and characterization equipment. Based on the results of review, this project is now proposed for construction funding in FY 2003.

[a] The full TEC Projection (design and construction) in the FY 2002 PED datasheet is a preliminary estimate based on conceptual data. The TEC displayed above is the TEC displayed in the FY 2003 construction datasheet for this project (03-R-312).

[b] Funding of $1,000,000 in FY 2003 and $2,000,000 in FY 2004 was identified in the FY 2002 Request for this project. Based on the results of peer review, this project will be funded at $1,500,000 in FY 2002 and $1,000,000 in FY 2003.

02-06: The Center for Integrated Nanotechnologies (CINT) – Sandia National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2002	3Q 2003	4Q 2003	N/A	4,200	30,000 – 60,000

Fiscal Year	Appropriations	Obligations	Costs
2002	1,000 [b]	1,000 [b]	1,000 [b]
2003	3,200 [b]	3,200 [b]	3,200 [b]

The Center for Integrated Nanotechnologies (CINT), a Center jointly managed by the Los Alamos National Laboratory (LANL) and Sandia National Laboratory (SNL), has as its primary objective the development of the scientific principles that govern the performance and integration of nanoscale materials, thereby building the foundations for future nanotechnologies. CINT will consist of a main research facility to be located in an unrestricted area just outside the restricted area at Sandia National Laboratory (SNL) and two smaller "gateway" facilities located on the campuses of SNL and LANL. These gateways will provide office space and, in the case of the LANL gateway limited amounts of laboratory space, for researchers who need access to specialized facilities located on these campuses. The SNL gateway will use existing space in SNL's Integrated Materials Research Laboratory; the LANL gateway will require construction of a small building. The CINT gateway to SNL will focus on specialized microfabrication and nanomaterials capabilities and expertise. The CINT gateway to LANL will focus on connecting CINT researchers to the extensive biosciences and nanomaterials capabilities at LANL. The main research facility and the gateways will be managed as one integrated facility by a single management structure. The CINT will focus on nanophotonics, nanoelectronics, nanomechnics, and functional nanomaterials. The Center will make use of a wide range of specialized facilities, including the Los Alamos Neutron Science Center and the National High Magnetic Field Laboratory at LANL; the Microelectronics Development Laboratory and the Compound Semiconductor Research Laboratory at SNL.

The main CINT building in Albuquerque will provide an open environment readily accessible by students and visitors, including foreign nationals. This structure will house state-of-the-art clean rooms and equipment for nanolithography, atomic layer deposition, and materials characterization along with general purpose chemistry and electronics labs and offices for Center staff and collaborators.

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline. CINT combines the projects identifies as the "Synthesis and Characterization Laboratory" at LANL and the "Nanofabrication and Integration Laboratory" at SNL described separately in FY 2002.

[b] The FY 2002 Request included a total of $1,000,000 in FY 2002 and $2,000,000 in FY 2003 for the LANL and SNL components of this combined project. Based on results of peer review, current PED funding plan for the combined project is $1,000,000 for FY 2002 and $3,200,000 FY 2003.

The complex will require class 1,000 clean room space for nanofabrication and characterization equipment and an additional class 100 clean room space for lithography activities. This facility will also require general purpose chemistry/biology laboratories and electronic and physical measurement laboratories. To house the Center staff, collaborators, Center-sponsored post docs, visiting students and faculty, and industry collaborators, offices and meeting rooms will be provided.

4. Details of Cost Estimate [a]

(dollars in thousands)

	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs (Design Drawings and Specifications)	11,250	10,500
Design Management costs (15% of TEC)	2,250	2,100
Project Management costs (10% of TEC)	1,500	1,400
Total Design Costs (100% of TEC)	15,000	14,000
Total, Line Item Costs (TEC)	15,000	14,000

5. Method of Performance

Design services will be obtained through competitive and/or negotiated contracts. M&O contractor staff may be utilized in areas involving security, production, proliferation, etc. concerns.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 2001	FY 2002	FY 2003	Outyears	Total
Facility Cost.						
PED	0	0	3,000	11,000	1,000	15,000
Other project costs						
Conceptual design cost	0	1,155	0	0	0	1,155
NEPA documentation costs	0	0	0	0	0	0
Other project related costs	0	0	0	0	0	0
Total, Other Project Costs	0	1,155	0	0	0	1,155

[a] This cost estimate is based on direct field inspection and historical cost estimate data, coupled with parametric cost data and completed conceptual studies and designs when available. The cost estimate includes design phase activities only. Construction activities will be requested as individual line items on completion of Title I design. The annual escalation rates assumed in the FY 2002 estimate for FY 2002 and FY 2003 are 3.3 and 3.4 percent, respectively.

	(dollars in thousands)					
	Prior Year Costs	FY 2001	FY 2002	FY 2003	Outyears	Total
Conceptual design cost........................	0	1,155	0	0	0	1,155
NEPA documentation costs..................	0	0	0	0	0	0
Other project related costs	0	0	0	0	0	0
Total, Other Project Costs	0	1,155	0	0	0	1,155

03-SC-002, Project Engineering Design (PED), Stanford Linear Accelerator Center

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost[1] ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Project Complete	
FY 2003 Budget Request (Preliminary Estimate)	1Q FY2003	2Q FY2005	1Q FY2004	4Q FY2006	$33,500

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2003	6,000	6,000	5,500
2004	15,000	15,000	15,500
2005	10,000	10,000	10,000
2006	2,500	2,500	2,500

3. Project Description, Justification and Scope

These funds allow designated projects to proceed from conceptual design into preliminary design (Title I) and definitive design (Title II). The design effort will be sufficient to assure project feasibility, define the scope, provide detailed estimates of construction costs based on the approved design and working drawings and specifications, and provide construction schedules including procurements. The design effort will ensure that construction can physically start or long-lead procurement items can be procured in the fiscal year in which Title III construction activities are funded.

The FY 2003 Request is for the Linac Coherent Light Source (LCLS) Project to be located at the Stanford Linear Accelerator Center (SLAC).

The purpose of the LCLS Project is to provide laser-like radiation in the x-ray region of the spectrum that is 10 orders of magnitude (i.e., a factor of 10,000,000,000) greater in peak power and peak brightness than any existing coherent x-ray light source. This advance in brightness is similar to that of a synchrotron over a 1960's laboratory x-ray tube. Synchrotrons revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to

[1] The full TEC Projection (design and construction) ranges between $165,000,000 and $225,000,000. This is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

be equally dramatic. The LCLS Project will provide the first demonstration of an x-ray free-electron-laser (FEL) in the 1.5 – 15 A range and will apply these extraordinary, high-brightness x-rays to an initial set of scientific problems. This will be the world's first such facility.

The LCLS is based on the existing SLAC linac. The SLAC linac can accelerate electrons or positrons to 50 GeV for colliding beams experiments and for nuclear and high-energy physics experiments on fixed targets. At present, the first two-thirds of the linac is being used to inject electrons and positrons into PEP-II, and the entire linac is used for fixed target experiments. When the LCLS is completed, this latter activity will be limited to 30 percent of the available beam time and the last one-third of the linac will be available for the LCLS a minimum of 70 percent of the available beam time. For the LCLS, the linac will produce high-brightness 5 - 15 GeV electron bunches at a 120 Hz repetition rate. When traveling through the 120 meter long LCLS undulator, these electron bunches will amplify the emitted x-ray radiation to produce an intense, coherent x-ray beam for scientific research.

The LCLS makes use of technologies developed for the SLAC and the next generation of linear colliders, as well as the progress in the production of intense electron beams with radio-frequency photocathode guns. These advances in the creation, compression, transport, and monitoring of bright electron beams make it possible to base this next generation of x-ray synchrotron radiation sources on linear accelerators rather than on storage rings.

The LCLS will have properties vastly exceeding those of current x-ray sources (both synchrotron radiation light sources and so-called "table-top" x-ray lasers) in three key areas: peak brightness, coherence (i.e., laser like properties), and ultrashort pulses. The peak brightness of the LCLS is 10 orders of magnitude greater than current synchrotrons, providing 10^{12}-10^{13} x-ray photons in a pulse with duration of 230 femtoseconds. These characteristics of the LCLS will open new realms of scientific applications in the chemical, material, and biological sciences. The LCLS Scientific Advisory Committee, working in coordination with the broad scientific community, identified high priority initial experiments that are summarized in the document, *LCLS: The First Experiments*. These first five areas of experimentation are fundamental studies of the interaction of intense x-ray pulses with simple atomic systems, use of the LCLS to create warm dense matter and plasmas, structural studies on single nanoscale particles and biomolecules, ultrafast dynamics in chemistry and solid-state physics, and studies of nanoscale structure and dynamics in condensed matter.

The experiments fall into two classes. The first follows the traditional role of X-rays to probe matter without modifying it while the second utilizes the phenomenal intensity of the LCLS to excite matter in fundamentally new ways and to create new states in extreme conditions. The fundamental studies of the interactions of intense X-rays with simple atomic systems are necessary to lay the foundation for all interactions of the LCLS pulse with atoms embedded in molecules and condensed matter. The structural studies of individual particles or molecules make use of recent advances in imaging techniques for reconstructing molecular structures from diffraction patterns of non-crystalline samples. The enormous photon flux of the LCLS makes it feasible to determine the structure of a *single* biomolecule or small nanocrystal using only the diffraction pattern from a single moiety. This application has enormous potential in structural biology, particularly for important systems such as membrane proteins, which are virtually uncharacterized by X-ray crystallography because they are nearly impossible to crystallize. The last two sets of experiments make use of the extremely short pulse of the LCLS to follow dynamical processes in chemistry and condensed matter physics in real time. The use of ultrafast X-rays will open up whole new regimes of spatial and temporal resolution to both techniques.

The proposed LCLS Project requires a 150 MeV injector to be built at Sector 20 of the 30-sector SLAC linac to create the electron beam required for the x-ray FEL. The last one third of the linac will be modified by adding two magnetic bunch compressors. Most of the linac and its infrastructure will remain unchanged. The existing components in the Final Focus Test Beam tunnel will be removed and replaced by a new 120 meter undulator and associated equipment.

4. Details of Cost Estimate[1]

(dollars in thousands)

	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs (Design Drawings and Specifications)	25,125	N/A
Design Management costs (15% of TEC)	5,025	N/A
Project Management costs (10% of TEC)	3,350	N/A
Total Design Costs (100% of TEC)	33,500	N/A
Total, Line Item Costs (TEC)	33,500	N/A

5. Method of Performance

A Conceptual Design Report (CDR) for the project will be completed and reviewed prior to beginning this work. Key design activities will be identified in the areas of the injector, undulator, x-ray optics and experimental halls that will reduce the risk of the project and accelerate the startup. Also, the management systems for the project will be put in place and proven during the Project Engineering Design (PED) phase. These activities will be managed by an LCLS project office in the Stanford Synchrotron Radiation Laboratory (SSRL) Division of SLAC. Portions of the project will be executed by staff at Argonne National Laboratory (ANL) and Lawrence Livermore National Laboratory (LLNL).

[1] This cost estimate includes design phase activities only. Construction activities will be requested to be funded in FY 2004.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 2001	FY 2002	FY 2003	Outyears	Total
Facility Cost						
PED	0	0	0	5,500	28,000	33,500
Other project costs						
Conceptual design cost	0	0	1,500	0	0	1,500
NEPA documentation costs	0	0	0	0	0	0
Other project related costs	0	0	0	0	0	0
Total, Other Project Costs	0	0	1,500	0	0	1,500
Total Project Cost (TPC)	0	0	1,500	5,500	28,000	35,000

03-R-312, Center For Nanophase Materials Sciences
Oak Ridge National Laboratory, Oak Ridge, Tennessee

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 2003 Budget Request (Preliminary Estimate)	2Q2002	1Q2003	3Q2003	4Q2006	$64,000	$65,000

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Project Engineering & Design (PED)			
2002	1,500[a]	1,500[a]	1,500[a]
2003	1,000[a]	1,000[a]	1,000[a]
Construction			
2003	24,000[a]	24,000[a]	14,000[a]
2004	20,000	20,000	20,000
2005	17,500	17,500	21,500
2006	0	0	6,000

[a] Funding of $1,000,000 in FY 2003 and $2,000,000 in FY 2004 was identified in the FY 2002 President's Request for this project. Based on the results of peer review, this project is now proposed for PED funding of $1,500,000 in FY 2002 and $1,000,000 in FY 2003 and construction funding of $24,000,000 in FY 2003.

3. Project Description, Justification and Scope

This proposed Center for Nanophase Materials Sciences (CNMS) will establish a nanoscale science research center at Oak Ridge National Laboratory (ORNL) that will integrate nanoscale science research with neutron science, synthesis science, and theory/modeling/simulation of nanophase materials, bringing together four areas where the United States has clear national research needs. The total gross area of the new building will be approximately 80,000 square feet, providing state-of-the-art clean rooms, and general laboratories for sample preparation, fabrication and analysis. Included will be initial equipment for nanoscale materials research such as surface analysis equipment, nanofabrication facilities, etc. The facility, collocated with the Spallation Neutron Source complex, will house ORNL staff members and visiting scientists from academia and industry. There are no existing buildings at ORNL that could serve these needs.

The CNMS's major scientific thrusts will be in nano-dimensioned soft materials, complex nanophase materials systems, and the crosscutting areas of interfaces and reduced dimensionality that become scientifically critical on the nanoscale. A major focus of the CNMS will be to exploit ORNL's unique facilities and capabilities in neutron scattering to determine the structure of nanomaterials, to develop a detailed understanding of synthesis and self-assembly processes in "soft" materials, and to study and understand collective (cooperative) phenomena that emerge on the nanoscale. Neutron scattering provides unique information (complementary to that provided by other methods) about both the atomic-scale structure and the dynamics of a wide variety of condensed matter systems including polymers, macromolecular systems, magnetic and superconducting materials, and chemically complex materials, particularly oxides and hydrogen-containing structures. The intense neutron beams available at the upgraded High Flux Isotope Reactor and the new Spallation Neutron Source will make broad classes of related nanoscale phenomena accessible to fundamental study.

Since the late 1980s, there has been a recognized need to enhance U.S. capabilities in the synthesis of materials. These concerns are exacerbated by the challenges of controlled synthesis of nanophase materials. There is currently a critical, unmet national need for the synthesis of high quality nanophase research materials. It is also recognized that the existence of capabilities for science-driven synthesis of novel materials has played a central role in some of the most spectacular recent discoveries of new phenomena, including high-temperature superconductivity, the quantum and fractional quantum Hall effects, conducting polymers, and colossal magnetoresistance. Therefore, synthesis and characterization of nanophase materials (including copolymers and macromolecular systems, multilayered nanostructures, ceramics, composites, and alloys with nanoscale spatial, charge, and/or magnetic ordering) will be an essential component of the CNMS. With these capabilities the CNMS will become a national resource for nanophase materials for use by researchers across the nation.

The scope of this project is to construct the Center for Nanophase Materials Sciences. The engineering effort includes preliminary and final design. The project also includes procurement of experimental capital equipment and construction of facilities. While no FY 2002 PED funds were identified for this project on the FY 2002 PED Project Data Sheet (02-SC-002, Project Engineering Design (PED), various locations), SC plans to allocate FY 2002 and FY 2003 PED funding to complete design of the CNMS. FY 2003 construction funding will be used to initiate construction and equipment procurement.

4. Details of Cost Estimate[1]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design Costs	1,700	N/A
Design and Project Management Costs	300	N/A
Total, Design Costs	2,000	N/A
Construction Phase		
Improvements to Land	500	N/A
New Building and Additions	19,700	N/A
Special Equipment[2]	26,000	N/A
Utilities	500	N/A
Inspection, design and project liaison, testing, checkout and Acceptance	1,800	N/A
Construction and Project Management	1,700	N/A
Total, Construction Costs	50,200	N/A
Contingency (23.5% of Construction Costs)[3]	11,800	N/A
Total, Line Item Costs	64,000	N/A
Less: Non-Agency Contribution	0	N/A
Total, Line Item Costs (TEC)	64,000	N/A

[1] The annual escalation rates are: FY 2002 – 2.6%, FY 2003 – 2.8%, FY 2004 – 2.8%, FY 2005 – 2.9% and FY 2006 – 2.9% as directed by DOE.
[2] Initial research equipment.
[3] Percent of TEC includes contingency for special equipment in the calculation.

5. Method of Performance

Design will be performed by an architect-engineer utilizing a fixed price subcontract. Construction will be performed by a fixed-price construction contractor administered by the ORNL operating contractor. Procurement of research capital equipment will be performed by the ORNL operating contractor. Project and construction management, inspection, coordination, utility tie-ins, testing and checkout witnessing, and acceptance will be performed by the ORNL operating contractor.

6. Schedule of Project Funding

	Prior Years	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	Total
Project Cost							
Facility Cost							
Design	0	1,500	1,000	0	0	0	2,500
Construction	0	0	14,000	20,000	21,500	6,000	61,500
Total, Line item TEC	0	1,500	15,000	20,000	21,500	6,000	64,000
Other project costs							
Conceptual design costs	150	0	0	0	0	0	150
NEPA documentation Costs	5	0	0	0	0	0	5
Other project related Costs [1]	0	220	100	250	175	100	845
Total, Other Project Costs	155	220	100	250	175	100	1,000
Total Project Cost	155	1,720	15,100	20,250	21,675	6,100	65,000
Less: Non-Agency Contribution	0	0	0	0	0	0	0
Total, Project Cost (TPC)	155	1,720	15,100	20,250	21,675	6,100	65,000

[1] Experimental research will begin at the time of beneficial occupancy of the facility. These research costs are not part of the TPC and are funded by the BES subprograms.

7. Related Annual Funding Requirements

(FY 2006 dollars in thousands)

	Current Estimate	Previous Estimate
Annual facility operating costs	$18,000	N/A
Total related annual funding	TBD	N/A
Total operating costs (operating from FY 2006 through FY 2055)	TBD	N/A

8. Design and Construction of Federal Facilities

All DOE facilities are designed and constructed in accordance with applicable Public Laws, Executive Orders, OMB Circulars, Federal Property Management Regulations, and DOE Orders. The total estimated cost of the project includes the cost of measures necessary to assure compliance with Executive Order 12088, “Federal Compliance with Pollution Control Standards”; section 19 of the Occupational Safety and Health Act of 1970, the provisions of Executive Order 12196, and the related Safety and Health provisions for Federal Employees (CFR Title 29, Chapter XVII, Part 1960); and the Architectural Barriers Act, Public Law 90-480, and implementing instructions in 41 CFR 101-19.6. This project will be located in an area not subject to flooding determined in accordance with the Executive Order 11988. DOE has reviewed the U.S. General Services Administration (GSA) inventory of Federal Scientific laboratories and found insufficient space available, as reported by the GSA inventory.

Nuclear Physics

Program Mission

The mission of the Nuclear Physics (NP) program is to foster fundamental research in nuclear physics that will provide new insights and advance our knowledge on the nature of matter and energy and develop the scientific knowledge, technologies and trained manpower that are needed to underpin the DOE's missions for nuclear-related national security, energy, and environmental quality. The Program provides world-class, peer-reviewed research results and operates user accelerator facilities in the scientific disciplines encompassed by the NP mission areas under the mandate provided in Public Law 95-91 that established the Department.

Strategic Objectives

SC2: By 2015, describe the properties of the nucleon and light nuclei in terms of the properties and interactions of the underlying quarks and gluons; by 2010, establish whether a quark-gluon plasma can be created in the laboratory and, if so, characterize its properties; by 2020, characterize the structure and reactions of nuclei at the limits of stability and develop the theoretical models to describe their properties, and characterize using experiments in the laboratory the nuclear processes within stars and supernovae that are needed to provide an understanding of nucleosynthesis.

SC7: Provide major advanced scientific user facilities where scientific excellence is validated by external review; average operational downtime does not exceed 10% of schedule; construction and upgrades are within 10% of schedule and budget; and facility technology research and development programs meet their goals.

Progress toward accomplishing these Strategic Objectives will be measured by Program Strategic Performance Goals, Indicators and Annual Targets, as follows:

Program Strategic Performance Goals

SC2-1: Determine the structure of nucleons in terms of bound states of quarks and gluons. Measure the effects of this structure on the properties of atomic nuclei. (Medium Energy Nuclear Physics and Nuclear Theory subprograms)

Performance Indicators

Results of external and internal reviews of quality, relevance and leadership of research activities and facility operations; number of significant scientific discoveries.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
As elements of the electron beam program, (a) completed fabrication of the BLAST detector at MIT/Bates in accordance with project milestones and (b) conducted precise studies of nucleon structure, including studies of the proton's internal charge distribution and role of QCD in nuclear structure by delivering high intensity (140 microamps), highly polarized (75%) electron beams with CEBAF at TJNAF. (SC4-1) [Met goal]	As elements of the electron beam program, (a) complete commissioning of the BLAST detector at MIT/Bates and initiate first measurements and (b) complete fabrication, installation and commissioning of the G0 detector, a joint NSF-DOE project, at TJNAF. (SC2-1)	As elements of the electron beam program, (a) complete first experiments with the BLAST detector at MIT/Bates, studying the structure of nucleons and few body nuclei and (b) map out the strange quark contribution to nucleon structure using the G0 detector, utilizing the high intensity polarized electron beam developed at TJNAF. (SC2-1)
	Commission polarized protons at RHIC. (SC2-1)	Collect first data with polarized protons with the RHIC STAR, PHENIX and pp2pp detectors. (SC2-1)

SC2-2: Determine the behavior and properties of hot, dense nuclear matter as a function of temperature and density. Discover and characterize the quark-gluon plasma. (Heavy Ion Nuclear Physics and Nuclear Theory subprograms)

Performance Indicators

Results of external and internal reviews of quality, relevance and leadership of research activities and facility operations; number of significant scientific discoveries.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Produced first heavy-ion collisions at the Relativistic Heavy Ion Collider (RHIC - construction completed FY1999) at 10% of its design luminosity, as planned, with four experimental detectors. Published first results of heavy-ion collisions. [Met Goal]	Complete first round of experiments at RHIC at full energy; achieve the full design luminosity (collision rate) of 2 x 10^{26} cm^{-2} s^{-1} for heavy ions. (SC2-2)	Initiate first round of experiments with collisions with other ions to compare to results of gold-gold collisions. (SC2-2)
Continued major accelerator improvement projects at RHIC in order to improve machine reliability and efficiency. [Met Goal]	Complete Helium Storage addition and liquid nitrogen standby cooling system at RHIC leading to better cost effectiveness ($0.5M savings) and operational efficiency (10% increase). (S2-2/SC7-2)	Upgrade the RHIC cryogenics system by replacing turbine oil skids and removing seal gas compressor, eliminating a single point failure. (S2-2/SC7-2)

SC2-3: Determine the low energy properties of nuclei, particularly at their limits of stability. Use these properties to understand energy generation and the origin of the elements in stars, and the fundamental symmetries of the "Standard Model" of elementary particle physics. (Low Energy Nuclear Physics and Nuclear Theory subprograms)

Performance Indicators

Results of external and internal reviews of quality, relevance and leadership of research activities and facility operations; number of significant scientific discoveries.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Produced first results on the solar neutrino flux with the Sudbury Neutrino Observatory (SNO). SNO measures properties of solar neutrinos. [Met Goal]	Collect the first data from neutral current interactions from SNO. (SC2-3)	Collect the first data from KamLAND, a joint U.S.-Japan experiment measuring neutrinos produced in nuclear reactors. (SC2-3)
Tested low-energy prototype of RIA fast catcher and tested low-beta accelerator cavities. [Met Goal]	Construct a prototype high energy, high power gas catcher for RIA. (SC2-3)	Complete testing the prototype high energy, high power gas catcher, and prototype targets for RIA. Complete prototype ECR ion source and work on the development of the high-beta superconducting RF cavities for RIA. (SC2-3)

SC7-2: Manage all NP facility operations and construction to the highest standards of overall performance, using merit evaluation with independent peer review. (Medium Energy Nuclear Physics, Heavy Ion Nuclear Physics, and Low Energy Nuclear Physics subprograms)

Performance Indicators

Percent on time/on budget; percent unscheduled downtime.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Maintained and operated NP scientific user facilities so that the unscheduled operational downtime was 15%, on average, of total scheduled operating time. [Met Goal]	Maintain and operate NP scientific user facilities so that the unscheduled operational downtime will be kept to less than 20%, on average, of total scheduled operating time. (SC7-2)	Maintain and operate NP scientific user facilities so that the unscheduled operational downtime will be kept to less than 20%, on average, of total scheduled operating time. (SC7-2)
Met the cost and schedule milestones for construction of facilities and Major Items of Equipment within 10% of baseline estimates. Completed on schedule the Analysis System for RHIC Detectors and RHIC Silicon Vertex Detector. [Met Goal]	Meet the cost and schedule milestones for construction of facilities and Major Items of Equipment within 10% of baseline estimates. Complete the PHENIX Muon Arm Instrumentation. (SC7-2)	Meet the cost and schedule milestones for construction of facilities and Major Items of Equipment within 10% of baseline estimates. Complete the RHIC STAR EMCAL. (SC7-2)

Significant Accomplishments and Program Shifts

In FY 2001, the DOE Nuclear Physics (NP) program was the major sponsor of fundamental nuclear physics research in the nation, providing about 90% of the federal support, with the National Science Foundation (NSF) providing most of the remaining support.

Over one-third of the program's funding was provided to scientists at universities and laboratories to conceive and carry out the research. The DOE NP program involves over 1900 researchers and students at over 100 U.S. academic, federal and private sector institutions. The program funds research activities at over 85 academic institutions located in 35 states and at 7 DOE Laboratories in 6 states. University researchers play a critical role in the nation's research effort and in the training of graduate students. About two-thirds of the nation's university researchers and graduate students doing fundamental nuclear physics research in FY 2001 were supported by the DOE Nuclear Physics program. Typically about 90 Ph.D. degrees are granted annually to students for research supported by the program. State-of-the-art facilities to address forefront physics are essential for the U.S. to maintain its world leadership role in nuclear physics research. They are necessary not only to make progress in our understanding of fundamental nuclear physics, but also to provide scientific opportunities for discovery that generate the interest and excitement to attract the brightest, most talented students.

The DOE Nuclear Physics program has made important discoveries in the past decade of great relevance to the field and DOE science missions. The assembly of a large set of precision nucleon-nucleon scattering data has provided critical input for theoretical models that now produce a significantly more quantitative description of nuclei, now making possible the development of a "Standard Model for Nuclei". The past decade has seen a growing interest by the field to understand nucleons in terms of the quarks and gluons of QCD. This interest has been spurred by advances in both theory and experiment. The discoveries in the late eighties that the quarks carried only 1/3 of the nucleon spin instead of all of it and that the velocity distributions of quarks in iron nuclei were different from those in deuterium raised interest in studying the roles of gluons and the nuclear medium in nucleon structure. This was the first clear evidence of nuclear medium effects at the quark level. The start of the Continuous Electron Beam Accelerator Facility (CEBAF) in 1995 at the Thomas Jefferson National Accelerator Facility, using a new superconducting radio-frequency (SRF) technology, provided a unique high-energy, high-intensity polarized electron beam, the "world's finest electron microscope," to perform detailed measurements of the structure of the nucleon and of light nuclei. This has led to the use of SRF for powerful new light and particle sources, worldwide, such as the Spallation Neutron Source. Recent results from CEBAF are revealing evidence of the transition from hadronic to quark degrees of freedom.

In the Heavy Ion program, after decades of search and study, the elusive transition of nuclear matter from a liquid to a gaseous phase was observed in the late 1990's. At much higher energies, the study of hot and extremely dense hadronic matter became possible with the advent of gold beams at the Alternating Gradient Synchrotron in 1992 and lead beams at the CERN SPS in 1994, where the U.S. played a substantial role in major experiments. The "fireball" systems formed in these collisions equilibrated rapidly and at a high temperature and density, producing conditions that indicated that the new phase of nuclear matter, the predicted quark-gluon plasma, would likely be formed at the even higher energies that would be available with the Relativistic Heavy Ion Collider at Brookhaven National Laboratory. First gold-gold collisions were observed at RHIC in 2000. With this new facility, the U.S. is leading the world effort in creating and characterizing the quark-gluon plasma, a new form of matter that is thought to have existed shortly after the "Big Bang."

The Low Energy subprogram embraces studies of nuclear structure and nuclear astrophysics, as well as related work in fundamental interactions and neutrino physics. The 1990's began with an effervescent research effort at the 88" Cyclotron, ATLAS, and other facilities to identify and characterize rapidly rotating superdeformed nuclei that have elongated football shapes. These spectroscopic studies have led to a deeper understanding of nuclear structure at high spin and large deformation. In 1997, the HRIBF facility became operational and is now producing over 100 proton-rich and neutron-rich radioactive beams. Research at these three facilities has explored nuclei at the extremes of nuclear spin, deformation, stability, and excitation energy. Stable beams and the first radioactive beams in the mid-1990's enabled nuclear structure and cross-section experiments to determine the nuclear reaction paths and some rates for the breakout from the stellar carbon-nitrogen-oxygen (CNO) cycle that leads to production of heavier elements. In neutrino physics following the pioneering work in solar neutrinos with radiochemical experiments, the SNO experiment was conceived in the late 1980's to search for neutrino flavor oscillations due to their having mass, and designed and built it in the 1990's. In 2001, SNO reported its first physics results, which, together with other experimental results, make a persuasive case for neutrino oscillations and that neutrinos have mass.

It has been known for a long time that nuclear structure cannot be explained fully using only two-body (nucleon-nucleon) interactions. The first fully converged calculations of the properties of the tri-nucleon (^3H and ^3He) ground states were completed in 1991. The description of the three-body system is one of the most fundamental problems of nuclear physics and had been studied for decades before this result. Recently, the origin of many collective modes of motion in even-even nuclei was explained by the interacting boson model, which makes use of the symmetry properties of valence neutron-proton pairs. In a series of papers published between 1989 and 1995, a new method for understanding the quark structure of matter via QCD was developed by focusing on systems in which one of the quarks is very heavy. This technique has led to a significant advance for using QCD to describe hadron structure. In the past five years, the availability of enormous computing power has allowed theorists to make spectacular progress on problems that were previously thought intractable. It is now possible to simulate complex nuclear physics processes at extreme length scales ranging from astrophysical objects, nuclei, to the quark structure of matter. The development of the Green's Function Monte Carlo Technique, as a solution to the nuclear many-body system, and the Monte Carlo Shell Model of nuclei are state-of-the-art computational methods that could provide a framework for a "Standard Nuclear Model" in the near future. In the last few years, large-scale parallel processor machines have been exploited to simulate QCD problems on a space-time lattice.

Recent accomplishments are detailed below.

SCIENCE ACCOMPLISHMENTS

Medium Energy Nuclear Physics

- *Role of the Strange Quark in the Structure of the Proton:* The SAMPLE experiment at Bates and the HAPPEX experiment in Hall A at TJNAF have provided information on the contribution of strange quarks to the electromagnetic form factors of the proton. The SAMPLE experiment was completed in FY 2001 and provided the first direct information on how different quark flavors in the quark "sea" contribute to the proton's magnetic moment. The HAPPEX experiment measured these form factors in a different kinematic regime than the SAMPLE experiment. Both found, quite unexpectedly, that the strange quarks play a small role in contributing to the electromagnetic form factors.
- *New Measurements of the Deuteron Provide Information on the Role of QCD in Nuclear Structure:* The deuteron is the simplest nucleus that can be formed, a bound proton and neutron. New measurements of deuteron structure functions at TJNAF allow scientists to study how well conventional nuclear models compare with calculations done by the full theory of Quantum Chromodynamics (QCD). Such measurements provide scientists with guidance on how to mathematically "connect" high-energy QCD calculations to low energy systems in which QCD cannot be calculated exactly.
- *New Precision Measurement of G_E^p / G_M^p Yields Surprising Results:* A recent experiment which measures the ratio of the proton's internal charge distribution to its magnetic (or current) distribution indicates that this ratio significantly decreases from unity as one probes as a function of increasing spatial resolution. This was unexpected since the charge distribution and current distributions are related and the ratio was expected to remain near unity. This experiment used a new technique that capitalizes on the high intensity polarized beam that is unique to TJNAF. The measurement is very important for understanding the internal quark structure of the proton and will constrain quark models of the proton that try to predict this effect. New measurements are planned which will go to even higher resolution to determine if the trend continues or reverses.
- *Recent Results on Flavor Asymmetry in the Nucleon's Quark "Sea:"* Recent publications of work done at Fermilab and the HERMES experiment at DESY in Germany clearly show a strong asymmetry in the number of "down" antiquarks compared to "up" antiquarks in the nucleon's "sea" of virtual quarks. The asymmetry varies significantly with the degree of momentum transferred to the struck quark in the "sea". This "sea" of virtual quarks and gluons is believed to play a significant role in the properties of the nucleon. Many theoretical models have been proposed to explain this asymmetry. Most of these models indicate that the asymmetry can be explained by the existence of virtual mesons in the nucleon. These results have distinct implications for the spin and flavor structure of hadrons that can be tested in future experiments.
- *Precision Measurements of an Excited State of the Nucleon Yield Information on its Dynamic Structure:* Recently published data from Hall B at TJNAF report on a resonance, an excited state of the nucleon, that has unusual properties which makes it possible that it is not a standard three-quark excited state of the nucleon. These new data will provide strong constraints on theoretical models that attempt to explain the resonance's properties.
- *First Determination of the Shrinkage of a Nucleus Due to the Presence of Strange Quarks:* Recent measurements by the HyperBall detector using the Alternating Gradient Synchrotron at Brookhaven National Laboratory have measured a 20% shrinkage in the nuclear radius of ^{7}Li when a neutron is changed into a Lamda (Λ) particle by exchanging a "down" quark with a "strange" quark, which is much heavier. While the shrinkage was expected, the magnitude of the effect was surprising. The precision of the measurement makes it possible to study the effect of this heavier quark in the

nuclear environment, giving us information on both the strange quark and the binding forces inside the nucleus.

- *Development of a New Isotope-Counting Technique with Potential for Important Applications:* A new precision technique for Atom Trap Trace Analysis (ATTA) to identify and count extremely rare isotopes has been developed at Argonne National Laboratory. The technique allows one to make precision measurements of the charge radius of several helium isotopes for fundamental tests of nuclear models and to measure the solar neutrino flux integrated over several million years as a test of the solar model prediction for neutrino production in the sun. The latter is an important test for understanding the low solar neutrino flux problem. This technique also potentially has broad new practical applications, such as dating ground water and polar ice for environmental and geologic studies, dating bones for archeological purposes, and, in medicine, monitoring bone loss in humans.

Heavy Ion Nuclear Physics

- *First Relativistic Heavy Ion Collider Results:* First RHIC measurements indicate that the energy density – a measure of the energy deposited in the collision region by the colliding nuclei – is the highest ever achieved in a laboratory, at least 70% higher than in similar experiments at CERN, and sufficient to create the long sought quark-gluon plasma (QGP), believed to be the state of matter of the universe shortly after the "Big Bang." Several papers reporting results have already been published and many others are expected to follow shortly. Discussion of these results dominated the premier international conference of this field - Quark Matter 2001.
- *3D Imaging:* Collisions between heavy ions create a brief microcosm of strongly interacting subatomic particles termed a "fireball". Using a correlation technique called HBT (Hanbury Brown Twiss) first applied to determine stellar sizes, physicists have measured the volume of the fireball created in the collisions at RHIC to be about as large as that of a gold nucleus. Two-particle correlations can be used to map out the time profile of hadron emission from the hot, dense matter.
- *Expansion of the Fireball:* In the most violent collisions at RHIC, over 5000 subatomic particles emanate from the fireball. By measuring their energies, scientists have determined that the fireball expands rapidly with a velocity approaching 2/3 the speed of light. This is evidence of the extremely rapid thermalization of the incident energy and its conversion into heating up the fireball.
- *Elliptic Flow:* The fireball emits particles asymmetrically in space. This information suggests the fireball geometry has an 'almond' shape – a result that has intrigued the scientific community. One theoretical model suggests this shape occurs as a consequence of pressure generated by an early fluid-like expansion of the quark-gluon plasma – a plasma of nearly massless quarks and gluons.
- *Abundance of Anti-matter:* Scientists have analyzed the constituents of the fireball and have found the ratio of baryonic matter and anti-matter to be nearly 0.8 (i.e., almost equal amounts of each). An equal mixture of matter and anti-matter is thought to have existed in the primitive universe. The RHIC observation is a preliminary indication that favorable conditions exist for QGP formation.
- *Jet Quenching:* A very energetic quark and anti-quark pair may decay into many subatomic particles focused in a narrow cone called a jet. First results suggest these 'hard scattered' pairs are created in a fireball with a high energy density. Jets lose energy as they travel through a QGP and, in turn, fewer subatomic particles are found with high energies. The preliminary RHIC data provide tantalizing hints of a suppression of high momentum subatomic particles. This quenching effect is not observed in lower energy collisions.

Low Energy Nuclear Physics

- *First Solar Neutrino Physics Results from SNO:* The first phase of data taking with the SNO solar neutrino experiment has been completed and the first published results report that neutrino oscillations, not lower than expected neutrino production by the sun, are the reason for deficits in solar neutrinos detected on earth. The SNO experiment is unique among solar neutrino experiments in that in its second experimental phase now underway it can also measure the appearance of non-electron neutrino flavors into which the solar electron neutrinos oscillate. If neutrinos oscillate, as first SNO results indicate, they must have a non-zero mass. These results will have profound implications for the present understanding of the Standard Model of fundamental particles and interactions.
- *Measurement of the $^{44}Ti(\alpha,p)$ Reaction Cross Section:* At ATLAS (ANL) the cross section for the ^{44}Ti (α,p) reaction has been measured experimentally for the first time using a beam of radioactive ^{44}Ti; this cross section has been determined to be significantly larger than previously estimated. ^{44}Ti can be used to identify and study supernovae remnants in the nearby cosmos because it has a half-life of 60 years and emits high-energy gamma rays. The use of the measured cross section for the ^{44}Ti (α,p) reaction in supernova explosion calculations results in lower residual ^{44}Ti in a supernova remnant, since this reaction process is a principal cause of ^{44}Ti destruction in these explosions. As the residual ^{44}Ti is less than previously assumed, this means that supernovae remnants studied by orbiting gamma-ray spectrometers are closer that previously believed.
- *First Identification Of The Di-Proton Decay Mode:* Decay of a nucleus by simultaneous emission of two protons has been identified for the first time by researchers at the ORNL HRIBF. The decaying nucleus, ^{18}Ne, was produced using a radioactive ^{17}F beam reacting with a hydrogen target. Future measurements will be undertaken to determine if the two protons are correlated (i.e., briefly interacting as a pair of protons) or uncorrelated (i.e., moving independently in the nucleus before decay). These data will provide information on the structure of nuclei near the proton dripline.
- *Characterization of the Superdeformed Band in ^{36}Ar:* The lifetimes of superdeformed states in the light Z = N nucleus ^{36}Ar have been measured with Gammasphere using beams provided by the ANL ATLAS facility. This information can be used to understand the microscopic origin of collective nuclear rotations. Superdeformed states occur in rapidly rotating nuclei that are oblong shaped with axes having ratios of about 2:1. Most of these are heavy nuclei where protons and neutrons are treated collectively by theoretical models. Since ^{36}Ar has comparatively few protons and neutrons, it may be possible to calculate the detailed properties of these states with the nuclear shell model that describes nuclei in terms of individual protons and neutrons.
- *First Evidence of Freeze-Out Effects in the S-Process:* At ORNL the resonance analysis of ^{192,194,195,196}Pt(n,γ) data from the Oak Ridge Electron Linac Accelerator (ORELA), and the study of the slow neutron capture process (s-process) branching at ^{192}Ir, have resulted in first evidence of long-sought freeze-out effects during s-process nucleosynthesis in a certain class of stars. These freeze-out effects involve the time dependence of the mean neutron density and temperature in the star as the capture process proceeds, thus providing details on stellar dynamics.
- *Observation and Characterization of Chiral Symmetry in Nuclei*: Scientists at several universities, including Yale University and the University of Tennessee, have identified twin bands of nuclear levels interpreted as resulting from chiral (mirror) symmetry. Although this symmetry in nuclei has been predicted theoretically it had never been experimentally observed. The existence of chiral symmetry requires specific conditions, including a deformed nucleus with an odd neutron and an odd proton. The spin vectors of the nuclear core, the odd neutron and the odd proton point in three

mutually perpendicular directions, forming either a right-handed or left-handed coordinate system and giving rise to the twin band structure.

Nuclear Theory

- *Advances in Neutron Star Science:* A number of theoretical nuclear astrophysicists have focused their recent efforts on understanding the characteristics of neutron stars. Increasingly realistic calculations are testing assertions that there may be condensation of kaons in these giant 'nuclei' and that there may be quasi-crystalline structure within them. Input to these studies includes both the fundamental understanding of particle interactions folded into massive numerical simulations, and experimental observations. The mass accretion properties of these stars have been deduced through study of 'X-ray bursters' that has shed light on both their equation of state and their rotational properties. The sudden spin-up behavior of pulsars known as 'glitches' has also been analyzed to yield an important new constraint on the mass-radius relationship for neutron stars that does not depend on their equation of state.
- *Quark Structure of the Deuteron:* New calculations have successfully explained the breakup of the deuteron into a proton and neutron by photons at high energies in terms of a single quark-level process. This is an important step toward understanding the quark and gluon degrees of freedom in nuclei, since deuterium is the simplest stable nucleus with more than a single nucleon. Previous theoretical attempts had successfully described the angular distributions of the emitted protons and neutrons fairly well, but predicted the basic probability of the breakup to occur to be 100 times too small. The new theory describes the data on average with better than 20% accuracy using only a single process; several further improvements are possible.
- *Thermalization in Ultra Relativistic Heavy Ion Collisions:* Recent work in perturbative QCD, the high-energy theory of the strong interaction, has determined that thermalization is guaranteed to occur for sufficiently high energies and sufficiently heavy nuclei in ultra relativistic heavy ion collisions. The system formed in the collision achieves thermal equilibrium surprisingly rapidly compared to the time required for it to fly apart, and the mechanism for achieving the equilibrium is an unexpected one. The thermal equilibrium condition, when achieved, greatly simplifies the interpretation of the particle spectrum ejected from the collision and permits much simpler calculations to describe the reaction.
- *New Theoretical Tool Ties Together Many Different Phenomena:* Generalized Parton Distributions (GPD's) were invented in recent years to describe certain exclusive high-energy electromagnetic reactions on the proton and neutron. GPD's have now been broadly linked to a much larger variety of electromagnetic observables or processes such as elastic form factors, high-energy meson production, inclusive deep-inelastic-scattering measurements, and virtual Compton scattering. The impact of this is that these distributions, when measured, will be able to be cross-correlated among these several very different types of reactions, testing the correctness of this theory and providing a compact description of a wide range of disparate phenomena.
- *Advances in Few-Body Reactions:* Low-energy properties of three-body systems such as ^{3}He have long been successfully described by a complicated method called Faddeev calculations. This method, while exact in principle, could not be extended to higher energies: the procedure fails to be practical because the number of angular momentum states becomes very large. A technical breakthrough in computational methods now permits a full three-dimensional solution of the Faddeev equations without using angular momentum decomposition; this will permit the method to be extended to higher energies. The first test of the new calculations against the older method has shown excellent agreement, verifying the new approach to very high accuracy.

- *Indicators of Quark-Gluon Plasma Formation:* While a number of indicators for the quark-gluon plasma have been proposed by theorists in the field, a particularly interesting method developed recently is that of event-by-event fluctuations in the ratio of particle types. A quark-gluon plasma is hoped to be formed in ultra-relativistic heavy-ion collisions such as those studied at RHIC. Fluctuations in the ratio of positively charged particles to negatively charged particles give a direct measure of the charge fluctuations per unit entropy. Since quarks in the quark-gluon plasma have only fractional charges (1/3 or 2/3 the charge of composite particles), the fluctuations are expected to be much smaller for the quark-gluon plasma compared to that in normal nuclear matter. This simple-sounding prediction has continued to hold up under detailed scrutiny by numerous researchers.

FACILITY AND TECHNICAL ACCOMPLISHMENTS

Medium Energy Nuclear Physics

- In FY 2001, the *Continuous Electron Beam Accelerator Facility at the Thomas Jefferson National Accelerator Facility Provided 140 Microamperes of Nearly 80% Polarized Beam at 5.7 GeV* (42% greater than the design energy of 4 GeV). These high intensity, highly polarized beam capabilities are unique in the world for electron accelerators. A newly developed diode laser with a Ti:Sapphire optical amplifier will make it possible to increase the intensity of this polarized beam by a factor of more than 500. In the past three years of full operations, 32 experiments have been completed and another 50 are partially completed, resulting in about 100 published papers and 60 Ph.D. theses.
- *CEBAF Represents the World's Most Powerful Superconducting Radio Frequency (SRF) Accelerator.* The SRF cavities have exceeded their design specifications by 50%, making it possible for CEBAF to accelerate 6 GeV beams. It is expected that further advances in SRF technology and the production of a new compact cryomodule could lead to a relatively simple and inexpensive upgrade of CEBAF's top energy to 12 GeV. R&D funding is provided in FY 2003 for this upgrade that is identified in the most recent NSAC long range planning exercise as a high priority opportunity that should be pursued.
- *RHIC Accelerates the Highest Energy Polarized Protons to Date.* The RHIC Spin program at Brookhaven National Laboratory successfully accelerated polarized protons in the RHIC rings to an energy of approximately 32 GeV with 20% polarization during its commissioning run in FY 2001 and reached an energy of 100 GeV in early FY 2002. This demonstrated that polarized protons can be successfully accelerated in the rings and set a record for the highest energy polarized proton beam ever achieved. This is not an easy accomplishment because the polarized protons are subject to depolarizing resonances as their energy is increased. Special approaches had to be developed to maintain the polarization during acceleration.
- The *BLAST Detector* at the MIT/Bates facility is nearing completion, and in FY 2002 a unique research program will be initiated to study the structure of the nucleon and few-body nuclei. The successful storage of 200 milliamperes of polarized beams in the South Hall Ring in FY 2001 demonstrated that the needed beam capabilities have been developed to carry out the BLAST research program in FY 2002-2004.
- *Fabrication of the G0 Detector* at the Thomas Jefferson National Accelerator Facility (TJNAF) is on cost and schedule to be completed in FY 2002 and initiate commissioning. It utilizes the very high intensity polarized electron beam developed at TJNAF in mapping out the strange quark contribution to nucleon structure over a wide range of momentum transfer.

- *Scintimammography and Molecular Imaging Developed at TJNAF:* In the past few years, the detector group at TJNAF has developed high resolution gamma imagers for biomedical applications. This is a device that "senses" gamma rays emitted by a tumor after absorption of a biological tracer and then builds an image of the tumor, thus improving breast cancer detection. In combining scintimammography and digital x-ray techniques, the group has designed a mini gamma camera for use in conjunction with a commercially available x-ray guidance system for stereotactically guided core needle breast biopsies.
- *Hyperpolarized Gas Provides Enhanced MRI Imaging:* A new technique has been developed by university researchers that enhances MRI imaging of lungs through the use of "hyperpolarized gas." The technique, initially developed to provide polarized targets for nuclear physics experiments, uses lasers to polarize large volumes of noble gases that can then be inhaled. The MRI equipment detects the resonance of the polarized gas to provide an image of the air volume of the lungs. The process is presently undergoing clinical trials.

Heavy Ion Nuclear Physics

- *Construction of the Relativistic Heavy Ion Collider (RHIC)* at Brookhaven National Laboratory was completed in FY 1999 on cost and schedule (TPC of $616,530,000). Commissioning started in FY 1999 and data taking started in FY 2000, as scheduled. During the FY 2000 run RHIC reached about 10% of its design luminosity (collision rate), as planned. RHIC reached operation at full luminosity for gold-gold collisions early in FY 2002.
- *Real Time Pattern Recognition and Tracking:* The STAR Time Projection Chamber is one of the most advanced instruments used to study heavy ion collisions, providing digital information from over 100,000 sensors. Scientists have developed software algorithms and built a farm of high-speed computers that sift through the sensor data to carry out pattern recognition. Images of thousands of tracks that are emitted in each head-on gold-gold collision are reconstructed in a fraction of a second in real time. The stunning STAR-burst pictures were published by news media throughout the world.
- *RHIC Detector Enhancements Remain on Cost and Schedule:* Fabrication of the STAR Silicon Vertex Detector (SVT), a high-resolution, high-granularity, charged-particle tracking system very close to the collision region, was successfully completed in FY 2000 and installed in FY 2001. The RHIC Data Analysis System was completed in FY 2000 and successfully recorded and stored the acquired experimental data that has been analyzed and published in several papers. One PHENIX Muon Arm will be completed and commissioned in FY 2001; the second Arm (funded substantially by Japanese collaborators) will be completed in FY 2002. The Electro-Magnetic Calorimeter (EMCal) for STAR began production fabrication of modules in FY 2000, will commission existing modules in FY 2001, and is on schedule for completion of the planned system in FY 2003. An enhancement of the EMCAL, providing additional modules for full coverage of the barrel and optimizing the performance for the RHIC Spin Program, will commence in FY 2003.

Low Energy Nuclear Physics

- *Production of Accelerated Radioactive Ion Beams:* In FY 2001 over 100 neutron-rich radioactive beams were produced and accelerated at the HRIBF at ORNL, the only facility in the world where these high-quality, high-energy beams are available for research. These accelerated neutron-rich radioactive beams are suitable for a variety of nuclear spectroscopy studies. The first spectroscopy experiments with these low-intensity beams utilized a combination of gamma-ray, charged-particle, and recoil-particle spectrometers, and included Coulomb excitation experiments and fusion and incomplete-fusion reactions.

- *Development of Crucial Technologies for the Rare Isotope Accelerator (RIA):* A prototype of the fast ion gas catcher, a technology that greatly extends the exotic beam production capability of RIA, was designed, built and successfully tested at ANL. A test of a full-scale version of the gas catcher will be mounted in the near future. The Versatile Electron Cyclotron Resonance (ECR) for Nuclear Science (VENUS) ion source, under construction at LBNL, is a test bed for technologies that will provide the high intensity ion source for the RIA driver linac and can be used to produce higher intensity beams at the other operating facilities such as ATLAS. Prototypes of several of the superconducting radiofrequency accelerator cavities have been built at ANL, including an intermediate energy cavity not previously designed.
- *First Nuclear Physics Experiments at the High Intensity Gamma-ray Source (HIγS):* The first nuclear physics experiments have begun at HIγS at TUNL for gamma-ray energies below 12 MeV. HIγS uses a special optical cavity at the Duke University Free Electron Laser to generate a narrow beam of mono-energetic high-energy gamma rays. An upgrade begun in FY 2001 will make this facility unique in the world in terms of the gamma-ray flux, energy range and attainable energy resolution it will provide for nuclear physics measurements.
- *The KamLAND Neutrino Detector*: The detector for the KamLAND experiment in Japan is nearing completion. This experiment will search for oscillation of neutrinos produced in distant nuclear reactors to test one of the possible solutions that are compatible with current atmospheric neutrino oscillation results. Scientists from the U.S., jointly supported by the Nuclear and High-Energy Physics programs, are collaborating with Japanese scientists in the construction and operation of KamLAND.
- *High Precision Mass Measurements:* In FY 2001 the first high-precision mass measurements of unstable nuclei have been accomplished with the Canadian Penning Trap at ATLAS (ANL). One of the technique's early uses will be the measurement of the mass of certain Z=N nuclei to completely characterize the Gamow-Teller beta decay of these nuclei, and place constraints on the Standard Model of weak interactions.
- *Development of Segmented Germanium Detectors:* Measurements using a 36-fold segmented germanium crystal at LBNL yield a three-dimensional position resolution of less that 1 mm for the determination of the position of a gamma-ray interaction in the crystal. When all of the interaction positions of a scattered gamma ray are known, the full energy and origin direction of the gamma ray can be reconstructed. This is a critical step in the development of a state-of-the-art tracking detector array that will be 1000 times more sensitive than Gammasphere, presently the most powerful gamma-ray detector in the world.
- *Development of a New Source for Ultra-Cold Neutrons:* Development of a source of ultra-cold neutrons is underway at LANL, and will be completed in FY 2003. Using a prototype source, scientists at LANL have exceeded by a factor of three the world's previous record for number of ultracold neutrons trapped. Further gains are expected with the full-scale source. This ultra-cold neutron source will allow the measurement of the details of neutron decay, and test aspects of the Standard Model.

PROGRAM SHIFTS

In the FY 2003 budget request the scientific scope of the nation's nuclear physics program is maintained. The FY 2003 budget request is focused on optimizing the utilization of its major user facilities. Facility operations are provided a 10% increase in funding in FY 2003 that will result in a 21% increase in beam hours for research compared to FY 2002. The research programs at these major user facilities are integrated partnerships between DOE scientific laboratories and the university community, and the planned experimental research activities are considered essential for effective utilization of the facilities. Funding for university and national laboratory research is increased about 4% compared to FY 2002, maintaining approximate constant level of effort. Funding for capital equipment is held essentially flat compared to FY 2002 and a 25% increase in R&D activities directed at RIA.

The Scientific Discovery through Advanced Computing (*SciDAC)* program is an Office of Science initiative to address major scientific challenges that require advances in scientific computing using terascale resources. An effort managed by the Office of High Energy and Nuclear Physics (HENP) identified the most compelling opportunities for advancements and for coordinated efforts in these two scientific fields by the application of terascale computing resources. This effort resulted in the identification of two such challenge areas within the domain of theoretical nuclear physics, and in FY2001 several major multi-institutional grants in high-priority topical areas were awarded through this program for the first time. One topical area is *Lattice QCD*. The collaboration involved represents essentially the entire U.S. community in this area with efforts from both nuclear and high-energy physics communities and strong involvement of both of the Nuclear Physics program's major accelerator facilities, TJNAF and RHIC. The scientific goal is to solve Quantum Chromodynamics (QCD), the fundamental theory of the strong interaction, on a 'lattice' of space-time points using advanced numerical methods. This is an extremely active area of inquiry world-wide, with major ongoing efforts in Europe and Japan. Of particular relevance to nuclear physics are the activities focused on solving QCD in two domains: the structure of the proton and neutron and their excited states, and the quark-gluon plasma that is anticipated to be produced at RHIC. A second topical area is *Theoretical Nuclear Astrophysics*, particularly focusing on supernova phenomena. Two types of supernova explosions are being modeled: Type Ia explodes because of nuclear reaction processes; types II, Ib, and Ic, are thought to explode through core collapse, fueled by neutrino energy transport. These problems are intrinsically multidisciplinary, involving nuclear physics, general relativity, neutrino science, hydrodynamics and transport theory, and advanced computing techniques. This is an ideal challenge to push the frontiers of advanced computing.

Scientific Facilities Utilization

The Nuclear Physics request includes $260,140,000 to maintain support of the Department's scientific user facilities. This investment will provide research time for several thousand scientists in universities and other Federal laboratories. It will also leverage both federally and privately sponsored research, consistent with the Administration's strategy for enhancing the U.S. national science investment.

The proposed funding will support operations at the six National User Facilities supported by the Nuclear Physics program: the Relativistic Heavy Ion Collider (RHIC) complex at Brookhaven National Laboratory (BNL), the Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility (TJNAF), the Bates Linear Accelerator Center at Massachusetts Institute of Technology (MIT), and the three low energy facilities: the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL), the Argonne Tandem Linac Accelerator System (ATLAS) facility at Argonne National Laboratory (ANL), and the 88-Inch Cyclotron at Lawrence

Berkeley National Laboratory (LBNL). Further information on these facilities can be found in the Site Description and Detailed Justifications under the subprogram in which they are funded.

These facilities provided about 20,000 hours of beams in FY 2001 for a research community of about 2,500 scientists. The FY 2003 President's Budget Request will support facility operations that will provide ~20,700 hours of beams for research, an increase of ~21% over the anticipated beam hours in FY 2002.

Workforce Development

The Nuclear Physics program supports development of the R&D workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research. It also provides talent for a wide variety of technical, medical, and industrial areas that require the finely-honed thinking and problem solving abilities, and the computing and technical skills, developed through an education and experience in a fundamental research field. Scientists trained as Nuclear Physicists can be found in such diverse areas as nuclear medicine, medical physics, space exploration, national security and the stock market.

About 800 postdoctoral research associates and graduate students supported by the Nuclear Physics program in FY 2001 were involved in a large variety of experimental and theoretical research projects. Nearly one quarter of these researchers are involved in theoretical research. Those involved in experimental research utilize a number of scientific facilities supported by the DOE, NSF, and foreign countries. The majority of the experimental postdoctoral associates and graduate students (~80%) conducted their research at the Nuclear Physics User Facilities. In FY 2003, emphasis is placed on operations and research efforts at the national user facilities. The funding level will result in approximately the same number of postdoctoral research associates and graduate students that can be supported compared to FY 2002.

Funding Profile

(dollars in thousands)

	FY 2001 Comparable Appropriation	FY 2002 Original Appropriation	FY 2002 Adjustments	FY 2002 Comparable Current Appropriation	FY 2003 Request
Nuclear Physics					
Medium Energy Nuclear Physics ..	113,410	117,953	-443	117,510	123,590
Heavy Ion Nuclear Physics	152,112	156,292	-674	155,618	167,977
Low Energy Nuclear Physics.........	62,650	62,685	-263	62,422	66,158
Nuclear Theory	23,622	23,580	-95	23,485	24,645
Subtotal, Nuclear Physics	351,794	360,510	-1,475	359,035	382,370
General Reduction.........................	0	-1,475	1,475	0	0
Total, Nuclear Physics........................	351,794 [a] [b]	359,035	0	359,035	382,370

Public Law Authorization:

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

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

[a] Excludes $7,760,000 that has been transferred to the SBIR program and $466,000 which has been transferred to the STTR program.

[b] Excludes $488,000 transferred to Science Safeguards and Security program in an FY 2001 reprogramming.

Funding by Site

(dollars in thousands)	FY 2001	FY 2002	FY 2003	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	10,378	9,643	9,123	-520	-5.4%
Sandia National Laboratory	4	0	0	0	--
Total, Albuquerque Operations Office	10,382	9,643	9,123	-520	-5.4%
Chicago Operations Office					
Argonne National Laboratory	17,912	16,532	17,548	+1,016	+6.1%
Brookhaven National Laboratory	140,791	138,671	149,004	+10,333	+7.5%
Fermi National Accelerator Laboratory	50	0	0	0	--
Chicago Operations Office	54,513	50,840	52,111	+1,271	+2.5%
Total, Chicago Operations Office	213,266	206,043	218,663	+12,620	+6.1%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	18,703	17,689	18,615	+926	+5.2%
Lawrence Livermore National Laboratory	755	614	507	-107	-17.4%
Oakland Operations Office	17,368	15,971	16,278	+307	+1.9%
Total, Oakland Operations Office	36,826	34,274	35,400	+1,126	+3.3%
Oak Ridge Operations Office					
Oak Ridge Institute for Science & Education	690	570	189	-381	-66.8%
Oak Ridge National Laboratory	15,879	15,307	16,870	+1,563	+10.2%
Thomas Jefferson National Accelerator Facility	74,135	73,830	79,138	+5,308	+7.2%
Total, Oak Ridge Operations Office	90,704	89,707	96,197	+6,490	+7.2%
Washington Headquarters	616	19,368	22,987	+3,619	+18.7%
Total, Nuclear Physics	351,794 [a] [b]	359,035	382,370	+23,335	+6.5%

[a] Excludes $7,760,000 that has been transferred to the SBIR program and $466,000 which has been transferred to the STTR program.

[b] Excludes $488,000 which was transferred to Science Safeguards and Security program in an FY 2001 reprogramming.

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. The major Nuclear Physics program activity at ANL supported by the Low Energy subprogram is the operation and research program at the ATLAS national user facility. Other activities include: (1) a Medium Energy group which carries out a program of research at TJNAF, Fermilab, RHIC and DESY in Germany; (2) R&D directed towards the proposed Rare Isotope Accelerator (RIA) facility; (3) a Nuclear Theory group, which carries out theoretical calculations and investigations in subjects supporting the experimental research programs in Medium Energy and Low Energy physics; and (4) data compilation and evaluation activities as part of the National Data Program.

The **Argonne Tandem Linac Accelerator System (ATLAS)** facility provides variable energy, precision beams of stable ions from protons through uranium, at energies near the Coulomb barrier (up to 10 MeV per nucleon) using a superconducting linear accelerator. Most work is performed with stable heavy-ion beams, however, about 6% of the beams are exotic (radioactive) beams. The ATLAS facility features a wide array of experimental instrumentation, including a world-leading atom trap apparatus. The Gammasphere detector, which ATLAS shares on a rotating basis with the LBNL 88-Inch Cyclotron, coupled with the Fragment Mass Analyzer is a unique world facility for measurement of nuclei at the limits of angular momentum (high-spin states). ATLAS is a world leader in superconducting linear accelerator technology, with particular application to the proposed Rare Isotope Accelerator (RIA) facility. The combination of versatile beams and powerful instruments enables the ~125 users annually at ATLAS to conduct research in a broad program in nuclear structure and dynamics, nuclear astrophysics, and fundamental interaction studies.

Brookhaven National Laboratory (BNL)

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The major Nuclear Physics program effort at BNL, supported by the Heavy Ion subprogram, is the operation and research program of the new Relativistic Heavy Ion Collider (RHIC). Other activities include (1) a Medium Energy group that will use polarized protons in RHIC to understand the internal "spin" structure of the protons, (2) the Laser Electron Gamma Source (LEGS) group, supported by the Medium Energy subprogram, that uses a unique polarized photon beam to carry out a program of photonuclear spin physics at the National Synchrotron Light Source (NSLS), (3) a Nuclear Theory group that does research primarily in the area of relativistic heavy ion physics, (4) a Low Energy group that plays an important role in the research program at the Sudbury Neutrino Observatory (SNO) that is measuring the solar neutrino flux, and (5) the DOE managed National Nuclear Data Center (NNDC) that is the central U.S. site for national and international nuclear data and compilation efforts.

The Relativistic Heavy Ion Collider (RHIC) Facility, completed in 1999, is a major new and unique international facility used by about 1,100 scientists from 19 countries. RHIC uses the Tandem, Booster, and Alternating Gradient Synchrotron (AGS) accelerators in combination to inject beams into two rings of superconducting magnets of almost 4 km circumference with 6 intersection regions where the beams collide. It can accelerate and collide a variety of heavy ions, including gold beams, up to an energy of 100 GeV per nucleon. RHIC will search for the predicted "quark-gluon plasma," a form of nuclear matter thought to have existed microseconds after the "Big Bang." Operations began in FY 2000 and first results have already been published. RHIC can also accelerate and collide polarized protons at energies up to 250 GeV for a research program directed at understanding the quark structure of the proton. Four detectors have been fabricated to provide complementary measurements, but with some overlap in order to cross-calibrate the measurements: (1) The core of the Solenoidal Tracker At RHIC (STAR) detector, built at a cost of ~$80,000,000, is a large Time Projection Chamber (TPC) located inside a solenoidal magnet that tracks thousands of charged particles emanating from a single head-on gold-gold collision. There are also end-cap TPC's. A large modular barrel Electro-Magnetic Calorimeter (EMCal), being fabricated with completion in FY 2003, measures deposited energy for high-energy charged and neutral particles and contains particle-photon discrimination capability. An enhancement to this calorimeter is being developed for the RHIC Spin program. An end-cap Calorimeter, also for the RHIC Spin program, is being funded by the NSF (TEC~$6,910,000; completion in FY 2004). A Silicon Vertex Tracker has very high tracking resolution for charged particles close to the collision vertex that greatly increases the tracking capabilities for the very short-lived multi-strange particles. (2) The Pioneering High-Energy Nuclear Interacting eXperiment (PHENIX) detector, built at a cost of ~$87,000,000, has a particular focus on the measurement of rarer probes at high event detection rate. It consists of two transverse smaller acceptance arms that can track charged particles within a magnetic field especially to higher momentum; it provides excellent discrimination among photons, electrons, and hadrons. There is also a Silicon Vertex Detector that can measure the total number of charged particles produced in a collision, but without particle identification. There are also two large muon tracking and identification systems in the forward and backward directions. (3) The PHOBOS detector, built at a cost of ~$7,600,000, is a very compact detector that uses mostly silicon pad sensors for charged particle detection and tracking, with a focus on measurements to very low momentum. It consists of two small-acceptance tracking arms located within a magnetic field and a very large coverage multiplicity detector that measures the total event charged-particle multiplicity and distribution. (4) The Broad Range Hadron Magnetic Spectrometer (BRAHMS) built at a cost of ~$6,200,000, has two very small acceptance magnetic spectrometer arms that be can rotated to scan the broadest range of angles. It is especially designed to study the charged particle distributions in the forward and backward directions.

The **Alternating Gradient Synchrotron (AGS)** provides high intensity pulsed proton beams up to 33 GeV on fixed targets and secondary beams of kaons, muons, pions, and anti-protons. Experiments explore the quark constituents of light nuclei, and test the theories of quantum chromo-dynamics and electro-weak forces. The AGS is the injector of (polarized) proton and heavy-ion beams into RHIC, and its operations are supported by the Heavy Ion subprogram as part of the RHIC facility. Operation of the AGS for fixed targets and secondary beams is terminated in FY 2003.

The **National Nuclear Data Center (NNDC)** is the central U.S. site for national and international nuclear data and compilation efforts. The U.S. Nuclear Data program is the United States repository for information generated in low- and intermediate-energy nuclear physics research worldwide. This information consists of both bibliographic and numeric data. The NNDC is a resource that maintains the U.S. expertise in low- and intermediate-energy nuclear physics by providing evaluated nuclear data for the user community. The NNDC is assisted in carrying out this responsibility by other Nuclear Data program funded scientists at U.S. National Laboratories and universities.

Lawrence Berkeley National Laboratory (LBNL)

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. A major Nuclear Physics effort at LBNL, supported by the Low Energy subprogram, is the operations and the research program of the 88-Inch Cyclotron, a national user facility. Other activities include (1) a Relativistic Nuclear Collisions group, with activities primarily at RHIC, where the group has been a major player in the development of the STAR detector; (2) a Low Energy group which has a major role in the implementation and operation of the Sudbury Neutrino Observatory (SNO) detector in Canada, and provides the project management of the U.S. collaboration in the KamLAND detector in Japan which is looking for evidence of neutrino mass; (3) a Nuclear Theory group that carries out a program with emphasis on the theory of relativistic heavy ion physics; (4) a Nuclear Data group whose activities support the National Nuclear Data Center at BNL; and (5) a technical effort involved in RIA R&D.

The **88-Inch Cyclotron** facility provides high intensity stable beams from protons to bismuth at energies above the Coulomb barrier (up to 15 MeV per nucleon). The electron-cyclotron resonance (ECR) ion sources at the facility are state-of-the-art and copied around the world. The Gammasphere array, widely regarded as the world's most powerful gamma-ray detector, is used to study nuclei at the extremes of angular momentum and excitation energy. The Berkeley Gas-filled Separator, a world-class instrument, is used for discovery experiments in superheavy elements. The 88-Inch Cyclotron is used annually by a community of about 230 scientists.

Lawrence Livermore National Laboratory (LLNL)

Lawrence Livermore National Laboratory is a Multiprogram Laboratory located on an 821 acre site in Livermore, California. Nuclear Physics supports research in nuclear structure studies carried out with the GENIE detector that was installed and is maintained by the LLNL group at the LANSCE facility at Los Alamos National Laboratory, in relativistic heavy ions as part of the PHENIX collaboration, for nuclear data and compilation activities, and for a technical effort involved in RIA R&D.

Los Alamos National Laboratory (LANL)

Los Alamos National Laboratory is a Multiprogram Laboratory located on a 27,000 acre site in Los Alamos, New Mexico. Nuclear Physics supports a broad program of research including: (1) a program of neutron beam research that utilizes beams from the LANSCE facility; (2) a relativistic heavy ion effort using the PHENIX detector at the new Relativistic Heavy Ion Collider (RHIC); (3) research directed at the study of the quark substructure of the nucleon in experiments at Fermilab, and at the "spin" structure of nucleons at RHIC using polarized proton beams; (4) the development of the Sudbury Neutrino Observatory (SNO) detector as well as involvement in the SNO and MiniBoone research programs; (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; and (7) a technical effort involved in RIA R&D.

Oak Ridge Institute for Science and Education (ORISE)

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

Oak Ridge National Laboratory (ORNL)

Oak Ridge National Laboratory is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The major effort at ORNL is the Low Energy program support for research and operations of the Holifield Radioactive Ion Beam Facility (HRIBF) that is operated as a national user facility. Also supported is (1) a relativistic heavy ion group that is involved in a research program using the PHENIX detector at RHIC; (2) a theoretical nuclear physics effort at ORNL that emphasizes investigations of nuclear structure and astrophysics; (3) nuclear data and compilation activities that support the national nuclear data effort; and (4) a technical effort involved in RIA R&D.

The **Holifield Radioactive Ion Beam Facility (HRIBF)** is the only radioactive nuclear beam facility in the U.S. to use the isotope separator on-line (ISOL) method and is used annually by about 100 scientists. It provides a wide range of both proton-rich and neutron-rich nuclei to a suite of instruments designed for studies in nuclear structure, dynamics and astrophysics using radioactive beams. The HRIBF accelerates secondary radioactive beams to higher energies (up to 10 MeV per nucleon) than any other facility in the world with such a broad selection of ions. The HRIBF conducts R&D on ion sources and low energy ion transport for radioactive beams.

Thomas Jefferson National Accelerator Facility (TJNAF)

Thomas Jefferson National Accelerator Facility (TJNAF) is a laboratory operated by the Nuclear Physics program located on 273 acres in Newport News, Virginia. Constructed over the period FY 1987-1995 for a cost of $513,000,000 (Total Project Cost), TJNAF began operations in FY 1995. Support for the research and operations of TJNAF are provided by the Medium Energy subprogram. The center piece of TJNAF is the **Continuous Electron Beam Accelerator Facility (CEBAF)**, a unique international electron-beam user facility for the investigation of nuclear and nucleon structure based on the underlying quark substructure that is used annually by 690 U.S. and foreign researchers. CEBAF consists of two multi-pass, superconducting linear accelerators connected by recirculating magnetic arcs. Polarized and unpolarized electron beams up to 5.7 GeV can be provided by CEBAF simultaneously to 3 different experimental halls, Halls A, B, and C. Hall A is designed for spectroscopy and few-body measurements. There are two high-resolution spectrometers, one for detection of the scattered electron from the beam and another for detection of the scattered particle. Hall B has a large acceptance detector, CLAS, for detecting multiple charged particles coming from a scattering reaction. Hall C is designed for flexibility to incorporate a wide variety of different experiments. Its core equipment consists of two medium resolution spectrometers for detecting high momentum or unstable particles. A large variety of major instruments are available for studying the scattering of and particle production from the electrons with fixed gas and solid targets. Fabrication of the G0 detector, a joint NSF-DOE project in Hall C that will allow a detailed mapping out of the strange quark contribution to nucleon structure, will be completed during FY 2002. As of FY 2002, Hall A will have completed 20 experiments and Hall C will have completed 18. The complex large-acceptance spectrometer in Hall B will have completed 65% of the data taking for 41 experiments. Support is also provided by the nuclear theory subprogram for a group whose program of investigations supports the experimental program of the laboratory. An accelerator R&D group is supported for projects important to the Nuclear Physics program (e.g., the proposed 12 GeV upgrade of CEBAF, and R&D for RIA).

All Other Sites

The Nuclear Physics program funds 180 research grants at 85 colleges/universities located in 35 states. Among these is a grant with the Massachusetts Institute of Technology (MIT) for the operation of the ***Bates Linear Accelerator Center*** as a national user facility used by about 110 scientists. The Bates facility, with electron beams up to 1 GeV, conducts experiments to study the properties and constituents of protons and light nuclei at energies below those of CEBAF. The research program probes the properties of the proton such as its shape and polarizability, and the charge distribution and magnetism of the deuteron. A major instrument for making these measurements will be the Bates Large Acceptance Spectrometer Toroid (BLAST) detector, whose fabrication will be completed in FY 2002. BLAST will observe collisions of polarized electrons in thin polarized gas targets located in the South Hall Pulse Stretcher Ring. Additional unique experiments are performed with the Out-Of Plane Spectrometer (OOPS). The Bates experimental program is scheduled to be concluded in 2004 and phased out in FY 2005-2006.

Grants for the operation of accelerator facilities at four university laboratories are supported by the Low Energy subprogram for research in selected and specialized areas conducted primarily by the in-house faculty members and students. The ***Triangle Universities Nuclear Laboratory (TUNL)*** utilizes a tandem Van de Graaff and polarized beams and targets to test and refine the theory of the nuclear force and its currents. A suite of instrumentation has been built up to take advantage of this unique combination of capabilities and to study fundamental symmetries and reactions important to nuclear astrophysics. ***The Texas A&M Cyclotron Institute (TAMU)*** operates a modern superconducting cyclotron to deliver a wide range of stable and selected radioactive beams for medium energy heavy-ion reaction studies, tests of fundamental constants of the standard model, and nuclear astrophysics. Modern instrumentation takes advantage of the heavy-ion beams, and a number of foreign collaborators use the facility. ***The Yale Tandem Van de Graaff*** provides a variety of stable beams for an extensive suite of instruments that, along with the opportunity for extended running times, provides the capability for detailed experiments on symmetry, collective structures, and evolution of properties in nuclei and nuclear astrophysics. The ***University of Washington Tandem Van de Graaff*** provides precisely characterized proton beams for extended running periods for research in fundamental nuclear interactions and nuclear astrophysics. These four accelerator facilities offer niche capabilities and opportunities not available at the national user facilities, or many foreign low-energy laboratories, such as specialized sources and targets, opportunities for extended experiments, and specialized instrumentation. These facilities operate in a university environment and thus provide a unique setting for the training and education of graduate students in the U.S., where they have the opportunity to be involved in all aspects of low energy nuclear research. These centers of excellence have in the past and continue today to produce the next generation of national leaders in nuclear science research.

The ***Institute for Nuclear Theory (INT)*** at the University of Washington is a premier international center for new initiatives and collaborations in nuclear theory research. Established in 1990, the INT conducts three programs each year on topics identified by an international advisory committee. U.S. and foreign researchers spend varying lengths of time at the Institute during the 2-3 month period of each program to establish collaborations and carry out projects. The institute also supports several workshops per year, some of which are hosted on-site. Currently, approximately 350 physicists visit the Institute per year, with an average stay of 3.5 weeks. Of these, approximately 20% are experimentalists, indicating the broad influence of the INT on nuclear physics research. About one-third of the attendees come from abroad, demonstrating the international stature of the Institute and its world leadership.

There are several major impacts of the INT operations. The first is that it fosters collaboration among researchers. These collaborative efforts, often multidisciplinary in nature, would not arise without the opportunity to spend an extended time focusing on specialty topics in an intellectually stimulating environment. A second major impact is the training of young people. Of the postdoctoral researchers who have been associated with the Institute over the last seven years, seven are now in academic positions and three more have staff positions at national laboratories. There are additional faculty, postdocs, and students in the local University of Washington nuclear theory group who synergistically interact with the INT activities, providing additional student and postdoctoral training. The third major impact is the work of the research group associated with the INT. The senior members of this group have a significant international stature and play a scientific leadership role both in their research work and in activities serving the scientific community.

For 2001, the three programs planned or underway are: "Correlations in Nucleons and Nuclei"; "Neutron Stars"; and "Lattice QCD and Hadron Phenomenology". In addition, there are three workshops: "RHIC-INT Workshop 2001"; "Theories of Nuclear Forces and Few-Nucleon Systems"; and "Computing $\sigma(DD \rightarrow \alpha\pi^o)$ and Charge Symmetry Breaking." These topics are at the core of modern nuclear physics, and the list displays an impressive breadth of scientific purview.

Medium Energy Nuclear Physics

Mission Supporting Goals and Objectives

The Nuclear Physics program supports the basic research necessary to identify and understand the fundamental features of atomic nuclei and their interactions. The Medium Energy Nuclear Physics subprogram supports fundamental research that is ultimately aimed at achieving a quantitative understanding of the structure of the atomic nucleus in terms of the quarks and gluons, the objects that are believed to be the building blocks of the sub-atomic particles. Equally important is the achievement of an understanding of the “strong force,” one of the four fundamental forces in nature, and the force that holds the nucleus of the atom together. Presently, the program supports different experimental approaches to gaining this knowledge: (1) determining the internal quark structure by electron scattering, (2) determining dynamic degrees of freedom by measuring the excited states of hadrons, (3) measuring the effects of the quark and gluon polarizations within the nucleon, and (4) determining the role of the “sea” of virtual quarks and gluons which also contributes to the properties of protons and neutrons. Measurements are normally carried out with beams of electrons or protons whose intrinsic spins have all been lined up in the same direction (polarized beams) to determine what role the intrinsic spins of the quarks and gluons play in the structure of the nucleon. In addition, the program supports research in understanding the structure of light nuclei and studies directed at testing fundamental symmetries. Most of this work is done at the primary research facility, Thomas Jefferson National Accelerator Facility (TJNAF), but the program also supports research at the Bates Linear Accelerator Center, the Relativistic Heavy Ion Collider at Brookhaven, the Stanford Linear Accelerator Center, Fermilab, and at several facilities in Europe. These facilities produce beams of sufficient energy (small enough wavelength) that they can probe at a scale within the size of a proton or neutron.

The two national user facilities, TJNAF and MIT/Bates, supported in Medium Energy Nuclear Physics, serve a nationwide community of about 300 Department of Energy and about 300 National Science Foundation supported scientists and students from over 140 American institutions, of which over 80% are colleges and universities. Both facilities provide major contributions to education at all levels. At both TJNAF and Bates, the National Science Foundation (NSF) has made a major contribution to new experimental apparatus in support of the large number of NSF users. A significant number of foreign scientists collaborate in the research programs of both facilities. The research program at the TJNAF, for example, involves about 300 scientists per year from 19 foreign countries; many of these scientists are from Conseil Europeen pour la Recherche Nucleaire (CERN) member states. At TJNAF, foreign collaborators have also made major investments in experimental equipment.

Funding Schedule

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Research					
University Research	16,506	15,300	15,575	+275	+1.8%
National Laboratory Research	15,357	15,980	16,815	+835	+5.2%
Other Research	457	5,415	5,405	-10	-0.2%
Subtotal, Research	32,320	36,695	37,795	+1,100	+3.0%
Operations					
TJNAF Operations	66,666	67,515	72,513	+4,998	+7.4%
Bates Operations	12,973	12,425	13,282	+857	+6.9%
Other Operations	1,451	875	0	-875	--
Subtotal, Operations	81,090	80,815	85,795	+4,980	+6.2%
Total, Medium Energy Nuclear Physics	113,410	117,510	123,590	+6,080	+5.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Research	**32,320**	**36,695**	**37,795**
▪ **University Research**	**16,506**	**15,300**	**15,575**

These activities comprise a broad program of research, and include 43 grants at 35 universities in 17 states and the District of Columbia in support of about 165 scientists and 110 graduate students. These research efforts utilize not only each of the accelerator facilities supported under the Medium Energy program, but also use other U.S. and foreign accelerator laboratories. Included in University Research is Bates Research, the effort performed at the MIT/Bates Linear Accelerator Center by MIT scientists. Other University Research includes all other university-based efforts using many research facilities, including activities by MIT scientists that are not carried out at Bates.

	FY 2001	FY 2002	FY 2003
▸ **Bates Research**	**3,985**	**2,520**	**2,835**

MIT scientists along with other university researchers have completed “mirror-symmetry violation” studies on the proton and deuteron in the North Experimental Hall. The experiment (SAMPLE) provides important information on the quark flavor contribution to the proton's spin magnetism.

Preparations are being made for a new program of research to study the structure of the nucleon and the nature of the nucleon-nucleon force, utilizing the new Bates Large Acceptance Spectrometer Toroid (BLAST) detector. Funding in FY 2003 is increased to effectively carry out the Bates research program. **Performance will be measured by** the initiation of measurements with BLAST on schedule in FY 2002 using thin gas targets and the high current circulating electron beam in the South Hall Pulse Stretcher Ring.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▸ **Other University Research**	**12,521**	**12,780**	**12,740**

In FY 2003 university research funds are about constant compared to FY 2002. The highest priority university research supports the activities associated with our main facilities at TJNAF, RHIC, and Bates. At the FY 2003 funding level, a shift in support from lower priority activities will be necessary to properly support these high priority activities. University scientists are collaborating on important ongoing and future experiments at TJNAF. These experiments are largely focused on the study of nucleon structure and its internal dynamics. Planned measurements in Hall A include the electric form factor of the proton and new parity-violation measurements to look for the "strange quark" content of the proton. New, higher-resolution measurements of the ratio of the electric to magnetic form factors of the proton are scheduled. Plans are also underway to carry out a new program of hypernuclear spectroscopy in Hall A in cooperation with researchers from Japan who will provide a new high-resolution spectrometer. A series of studies of the excited states of the proton will continue in Hall B. In Hall C, the newly constructed "G0" experiment will be commissioned in FY 2002 and begin experimental runs in FY 2003. "G0" will allow a "complete mapping" of the strange quark content of the nucleon using parity-violation techniques.

A number of university groups are collaborating in experiments using the new BLAST detector and the South Hall Ring at the MIT/Bates Linear Accelerator Center. BLAST will be used to perform precision polarization measurements of the proton and nuclear structure measurements on light nuclei. It will also be used to measure critical cross sections to improve our understanding of the oxygen-carbon cycle in stellar burning.

University scientists and National Laboratory collaborators will continue to develop the RHIC Spin program at Brookhaven National Laboratory. This program is expected to provide critical information on the contribution of gluons to the nucleon's intrinsic spin. Complementary research presently carried out by the HERMES (HERa MEasurements with Spin) experiment at the DESY laboratory in Hamburg, Germany will be reduced as the RHIC-spin physics program grows.

Supported also are university researchers involved in polarization experiments conducted at the SLAC (Stanford Linear Accelerator Center) facility, aimed at making a precise determination of the weak mixing angle, an important fundamental parameter of the Standard Model of Particle Physics, and fundamental measurements at the Paul Scherrer Institute in Switzerland to measure the proton charge radius using muons captured in atomic orbits.

▪ **National Laboratory Research**..	**15,357**	**15,980**	**16,815**

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

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▸ **TJNAF Research**	**5,746**	**5,770**	**5,945**

Scientists at TJNAF, with support of the user community, assembled the large and complex new experimental apparatus for Halls A, B, and C. TJNAF scientists provide experimental support and operate the apparatus for safe and effective utilization by the user community. TJNAF scientists participate in the laboratory's research program, and collaborate in research at other facilities.

As of FY 2002, Hall A will have completed 20 experiments and Hall C will have completed 18. The complex large-acceptance spectrometer in Hall B will have completed 65% of the data taking for 41 experiments. TJNAF researchers participate in all of these experiments.

TJNAF scientists are participating in the assembly of a new detector for the G0 experiment, in cooperation with the National Science Foundation (NSF contribution of $3,605,000) for combined TEC of $7,570,000. The G0 detector will map out the contribution of the strange quark to the nucleon; it will be commissioned in FY 2002.

▸ **Other National Laboratory Research**.........................	**9,611**	**10,210**	**10,870**

Support for researchers at National Laboratories is increased by 6.5% relative to FY 2002 levels to address forefront science at accelerator and non-accelerator facilities. These activities include:

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 quark-gluon structure of the nucleon. They have also made important advances in the technique of Atom Trap Trace Analysis to be used in measurements of rare isotopes for precision studies of nuclear structure and a measurement of the integrated solar neutrino flux over a long time scale (approximately one million years).

At Brookhaven National Laboratory, the Medium Energy Research group, which in previous years has concentrated on hadron beam experiments at the AGS, has changed its major emphasis to "RHIC Spin". This is the set of experiments planned for RHIC that will use colliding polarized proton beams to investigate the spin content of the nucleon and, in particular, what role gluons play. In FY 2002-2003, additional funding is being provided to this group to assure that appropriate scientific effort has been assembled in support of the RHIC Spin effort.

Also at Brookhaven, Laser Electron Gamma Source (LEGS) scientists will be utilizing a new spectrometer and a recently-developed polarized "ice" target for a program of spin physics at low energies. This unique facility produces its polarized "gammas" by back scattering laser light from the circulating electron beam at the National Synchrotron Light Source (NSLS). In FY 2003, the research program utilizing the new equipment will commence.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

At Los Alamos National Laboratory, scientists and collaborators have developed a next-generation neutrino oscillation experiment that builds on the experience of the Liquid Scintillator Neutrino Detector (LSND) experiment at Los Alamos, which detected a signal consistent with the existence of neutrino oscillations. This experiment, the Booster Neutrino Experiment (BooNE), uses neutrinos generated from the Fermi National Accelerator Laboratory Booster proton beam; data collection is planned to commence in FY 2002.

Los Alamos scientists also are involved in experiments at Fermilab and at RHIC (RHIC Spin) that will probe the structure of the virtual quark "sea" of the nucleon and the gluonic contribution to its spin, respectively. The Los Alamos group has also been instrumental in providing major components of the PHENIX detector at RHIC that are crucial in carrying out the RHIC Spin program of research.

	FY 2001	FY 2002	FY 2003
▪ **Other Research**	**457**	**5,415**	**5,405**

In FY 2001 $4,273,000 was transferred to the SBIR program and $466,000 was transferred to the STTR program. This section includes $4,403,000 for SBIR and $479,000 for STTR in FY 2002 and $4,346,000 for SBIR and $510,000 for STTR in FY 2003 and other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

	FY 2001	FY 2002	FY 2003
Operations	**81,090**	**80,815**	**85,795**
▪ **TJNAF Operations**	**66,666**	**67,515**	**72,513**

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

	FY 2001	FY 2002	FY 2003
▸ **TJNAF Accelerator Operations**	**42,790**	**42,910**	**46,413**

Funding for accelerator operations in FY 2003 supports a 4,200 hour (28-week) running schedule. In FY 2001, the accelerator routinely delivered beams of differing energies and currents simultaneously to the three experimental halls. A maximum beam energy of 5.7 GeV has been delivered to experiments. High current, high polarization beam capability is now also available and is being used for experiments.

	(hours of beam for research)		
	FY 2001	FY 2002	FY 2003
TJNAF	4180	3900	4200

Funding of $500,000 is provided for R&D for the proposed upgrade of CEBAF to 12 GeV. AIP funding includes polarized injector and beam handling components as well as other additions and modifications to the accelerator facilities. GPP funding is provided for minor new construction and utility systems.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▸ **TJNAF Experimental Support**....................................	**23,876**	**24,605**	**26,100**

Operating and equipment funding is provided for the experimental support needed to effectively carry out the TJNAF experimental program.

Support is increased by $1,495,000 (6.0%) for the scientific and technical manpower, materials, and services needed to support three hall operations and to integrate rapid assembly, modification, and disassembly of large and complex experiments for optimization of schedules. This includes the delivery or dismantling of cryogenic systems, electricity, water for cooling, radiation shielding, and special equipment for specific experiments.

The G0 detector, a major item of equipment with a Total Estimated Cost of $7,570,000 has been assembled. DOE's contribution was $3,965,000 and the National Science Foundation contributed $3,605,000 to this detector. With G0 fabrication completed in FY 2002, TJNAF is shifting their base capital equipment towards assembly and installation of ancillary equipment items such as polarized targets for experimental Halls A, B, C, spectrometer systems, the completion of a major upgrade of the data reduction system to handle massive amounts of raw data, and the continuation of the fabrication of second generation experiments. **Performance will be measured by** the completion of fabrication, commissioning and initiation of measurements with the G0 detector in FY 2002.

▪ **Bates Operations**	**12,973**	**12,425**	**13,282**

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

Bates Operations in FY 2003 will be focused on the initiation of the research program of the BLAST detector completed in FY 2002. The new BLAST detector will observe collisions in thin gas targets located on the South Hall Pulse Stretcher Ring. **Performance will be measured by** the commissioning of the BLAST detector and the initiation of its research program in FY 2003. When the scientific program of BLAST commences, the Bates research effort will concentrate on this new experimental facility. Upon completion of the BLAST research program in FY 2004, it is now planned that the Bates facility will begin a two-year phaseout. Starting in FY 2005, Decontaminating and Decommissioning (D&D) activities will be initiated. The D&D cost and schedule will be determined at that time.

	(hours of beam for research)		
	FY 2001	FY 2002	FY 2003
Bates..	1800	2100	2700

Accelerator operations in FY 2003 are funded at a level to provide the needed beams to carry out the research program in the South Hall Ring using the BLAST detector. Capital Equipment and AIP funding is maintained at the FY 2002 level to support maintenance of the accelerator and experimental facilities.

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		
▪ **Other Operations**	**1,451**	**875**	**0**

Operation of the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory for a limited target program is terminated.

Total, Medium Energy Nuclear Physics	**113,410**	**117,510**	**123,590**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Research	
▪ **University Research**	
▸ The MIT/Bates research support (+12.5% over FY 2002) is provided to effectively carry out the Bates research program whose focus is the new BLAST detector.	+315
▸ Research support at Other Universities is slightly decreased (0.3%). Lower priority activities will be phased out in order to maintain manpower and focus efforts on the high priority activities at TJNAF, RHIC-Spin, and Bates.	-40
Total, University Research	+275
▪ **National Laboratory Research**	
▸ Funding for TJNAF and other National Laboratory groups is increased by about 4%. Resources will be directed to maintaining manpower and focus on the high-priority activities at TJNAF and RHIC-Spin.	+835
▪ **Other Research**	
▸ Estimated SBIR/STTR and other obligations decrease	-10
Total Research	+1,100
Operations	
▪ **TJNAF Operations**	
▸ **TJNAF Accelerator Operations:** Funding for accelerator operations is increased by about $3,413,000 (+8.3%) relative to FY 2002 in order to provide a 4200 hour (28 week) running schedule. A decrease of $500,000 for AIP is offset by an increase of $500,000 for R&D for the proposed 12 GeV upgrade of CEBAF. GPP is increased by $90,000 (to $440,000).	+3,503

	FY 2003 vs. FY 2002 ($000)
▸ **TJNAF Experimental Support:** Experimental Support is increased by $1,495,000 in order to provide increased manpower and equipment needed for carrying out the experimental program. Overall Capital Equipment funding ($6,100,000) remains the same as FY 2002.	+1,495
Total, TJNAF Operations	+4,998
▪ **Bates Operations**	
▸ The increased funding for Bates operations increases the running schedule over FY 2002 to carry out research with the new BLAST detector. Bates will provide 2700 beam hours that will be focused on the commissioning of the BLAST detector and the initiation of its research program.	+857
▪ **Other Operations**	
▸ Funding of the operation of the AGS at BNL for producing secondary meson beams for fixed-target experiments is terminated.	-875
Total Operations	+4,980
Total Funding Change, Medium Energy Nuclear Physics	+6,080

Heavy Ion Nuclear Physics

Mission Supporting Goals and Objectives

The Heavy Ion Nuclear Physics subprogram supports research directed at understanding the properties of nuclear matter over the wide range of conditions created in nucleus-nucleus collisions, particularly the predicted phase changes from the liquid to gas state and from normal to quark matter. Using beams of accelerated heavy ions at intermediate bombarding energies, research is focused on the study of the fragmentation of nuclei in highly violent collisions and the flow of nuclear matter in less violent collisions. From such studies of the flow of nuclear matter, one can obtain information regarding the equation of state of nuclear matter; such information is important in understanding the dynamics of supernova explosions. At much higher relativistic bombarding energies, collisions producing hot**,** dense nuclear matter are studied with the goal of observing the deconfinement of normal matter into the quark-gluon plasma. This form of matter is predicted to have been the early phase of the universe, a millionth of a second after the Big Bang. Scientists and students at universities and national laboratories are funded to carry out this research at the DOE supported Relativistic Heavy Ion Collider (RHIC) facility, as well as at the National Science Foundation (NSF) and foreign supported accelerator facilities.

The Heavy Ion Nuclear Physics subprogram supports operation of RHIC at Brookhaven National Laboratory (BNL). This is a unique world-class facility that addresses fundamental questions about the nature of nuclear matter. With it one can study collisions of heavy nuclei at energies over 10 times of that previously available at any other facility in the world, namely at CERN. The RHIC is also the only accelerator facility in the world that provides collisions of polarized protons with polarized protons. From these collisions, important and unique information can be obtained regarding the composition of the gluons that provide the binding of the quarks to make the nucleons, the protons and neutrons that make up the nucleus. The construction of RHIC was completed in August 1999, and first collisions were observed in June 2000. The RHIC facility is utilized by over 1,100 DOE, NSF, and foreign supported researchers. The RHIC experimental program is determined with the guidance of a Program Advisory Committee, consisting of distinguished scientists, that reviews and evaluates proposed experiments and advises the BNL Associate Director for Nuclear and High Energy Physics regarding their merit and scientific priority. Capital Equipment and 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. An annual peer review of the effectiveness of RHIC operations and its research program is conducted by the program.

The Heavy Ion Nuclear Physics subprogram also provides General Purpose Equipment (GPE), General Plant Project (GPP), and other funding as part of Nuclear Physics' stewardship responsibilities for this laboratory. These funds are for general purpose equipment, minor new capital construction, alterations and additions, improvements to land, buildings, and utility systems, and other normal operations.

Funding Schedule

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Research					
University Research	11,776	11,390	11,635	+245	+2.2%
National Laboratory Research	20,760	20,324	21,194	+870	+4.3%
Other Research	0	2,903	3,291	+388	+13.4%
Subtotal, Research	32,536	34,617	36,120	+1,503	+4.3%
Operations					
RHIC Operations	103,991	103,505	117,497	+13,992	+13.5%
Other Operations	15,585	17,496	14,360	-3,136	-17.9%
Subtotal, Operations	119,576	121,001	131,857	+10,856	+9.0%
Total, Heavy Ion Nuclear Physics	152,112	155,618	167,977	+12,359	+7.9%

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Research	**32,536**	**34,617**	**36,120**
▪ **University Research**	**11,776**	**11,390**	**11,635**

Support is provided for the research of about 130 scientists and 75 graduate students at 26 universities in 18 states.

- Researchers using primarily the NSF supported National Superconducting Cyclotron Laboratory at Michigan State University, at Texas A&M University, and at foreign facilities in France, Germany, and Italy, investigate nuclear reactions at intermediate energies, with the aim of studying the fragmentation of nuclei and the flow of nuclear matter in violent collisions.
- Research using relativistic heavy ion beams is focused on the study of the production and properties of hot, dense nuclear matter at experiments at RHIC, where an entirely new regime of nuclear matter now becomes available to study for the first time. The university groups provide core manpower for the operation of and data analysis for the RHIC detectors. There is a $245,000 increase compared to FY 2002 that provides a 2.2% increase in grant funding.

▪ **National Laboratory Research**	**20,760**	**20,324**	**21,194**

Support is provided for the research programs of scientists at five National Laboratories (BNL, LBNL, LANL, LLNL and ORNL). These scientists provide essential manpower for the operations of the RHIC detectors. Also, BNL, LBNL, and LLNL provide substantial computing infrastructure for terabyte-scale data analysis and state-of-the-art facilities for detector and instrument development. The 4.2% increase provides an approximate constant level of effort.

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		
▸ **BNL RHIC Research**...	**10,990**	**10,065**	**9,153**

BNL scientists play a major role in planning and carrying out research with the four detectors (STAR, PHENIX, BRAHMS and PHOBOS) at RHIC and have major responsibilities for maintaining, improving and developing this instrumentation for use by the user community. In FY 2003 with RHIC operating at its design luminosity (collision rate). All four detectors will be capable of discovering signatures of any new forms of nuclear matter in the heavy ion collisions. In FY 2003 funding for capital equipment decreases by $1,012,000 with the completion of projects. The PHENIX muon instrumentation will be fully ready for commissioning. Funding begins for production of modules for the Electromagnetic Calorimeter Enhancement for the STAR RHIC-spin program. Although it is anticipated that this survey work with gold ions will be substantially complete by the end of the FY 2002 run, comparison running with light-ion beams, particularly the deuteron – nucleus collision operation, will not commence before FY 2003.

- The muon instrumentation for PHENIX allows measurement of the yields of muons ("heavy electrons") that probe the early stages of quark-gluon plasma formation will be completed in FY 2002. The Japanese and French are contributing substantial support for the PHENIX muon arms; they are also critical components of the detection systems for measurements in the PHENIX RHIC Spin program.
- The Electromagnetic Calorimeter for STAR provides capability to distinguish electrons from photons, and extends the measurement of particle energy to high energies. The detector system is also a critical component for the RHIC Spin program for STAR. Production of calorimeter modules began in FY 2000 and will be completed in FY 2003. An enhancement to the Electromagnetic Calorimeter, providing additional modules for full coverage of the barrel as well as improved electron/photon discrimination required for the RHIC Spin program, will be initiated in FY 2003.

▸ **Other National Laboratory Research**.............................	**9,770**	**10,259**	**12,041**

Researchers at LANL, LBNL, LLNL, and ORNL provide leadership in the commissioning of the PHENIX muon arm and the STAR electromagnetic calorimeter, as well as play leadership roles in carrying out the research utilizing these detectors. At LBNL an analysis system for RHIC data, in alliance with the National Energy Research Scientific Computing Center (NERSC), is a major resource for data analysis by the STAR collaboration and at LLNL substantial computing resources are made available for PHENIX data analysis. A 7.0% increase of $638,000 for research groups compared to FY 2002 is provided to help restore approximately constant level of effort for the National Laboratory research effort that has been reduced by steady attrition in recent years. An increase of $1,144,000 for capital equipment is provided for computing and other projects important for the RHIC program.

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		
▪ **Other Research**	**0**	**2,903**	**3,291**

In FY 2001 $2,848,000 was transferred to the SBIR program. This section includes $2,903,00 for SBIR in FY 2002 and $3,291,000 for SBIR in FY 2003.

	FY 2001	FY 2002	FY 2003
Operations	**119,576**	**121,001**	**131,857**
▪ **RHIC Operations**	**103,991**	**103,505**	**117,497**

The Relativistic Heavy Ion Collider (RHIC) is anticipated to reach nearly full data production capabilities by the end of the planned running period in FY 2002. RHIC is a unique facility whose colliding relativistic heavy ion beams will permit exploration of hot, dense nuclear matter and recreate the transition from quarks to nucleons that characterized the early evolution of the universe. Studies with colliding heavy ion beams provide researchers with an opportunity to explore a new regime of nuclear matter and nuclear interactions that up to now has only been characterized theoretically. Already during the initial brief run in FY 2000, new features were observed in the data, indicating that conditions are favorable for quark-gluon formation and hints of some characteristic signatures of its existence. The flurry of scientific papers that have been published from these initial results has generated much attention in the press. During the FY 2001-FY 2002 running periods, preparations of RHIC for its spin-physics program will continue, with the anticipation that this experimental program will begin in FY 2003.

	FY 2001	FY 2002	FY 2003
▸ **RHIC Accelerator Operations**	**75,275**	**76,345**	**86,950**

Support is provided for the operation, maintenance, improvement and enhancement of the RHIC accelerator complex. This includes the Tandem, Booster and AGS accelerators that together serve as the injector for RHIC. RHIC produced its first collisions in June 2000. Beam time for research increased significantly in FY 2001 with a 13-week operating schedule (1880 hours). FY 2002 funding provides 1,650 hours of beam for research and beam studies and for commissioning operations with polarized protons. FY 2003 funding will support a 22-week schedule (3300 hours) for research. **Performance will be measured by** initiating the first round of experiments with collisions with other ions to compare to results of gold-gold collisions. Capital equipment funding is provided for normal maintenance projects and AIP funding is provided for needed improvement projects. An increase of $400,000 is provided for AIP in order to upgrade the RHIC crygenics system, by replacing turbine oil skids and removing the seal gas compressor, eliminating a single-point failure.

RHIC Operations

	(hours of beam for research)		
	FY 2001	FY 2002	FY 2003
RHIC	1880	1650	3300

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▸ **RHIC Experimental Support**	**28,716**	**27,160**	**30,547**

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. The RHIC detectors (STAR, PHENIX, BRAHMS and PHOBOS) will reach their initial planned potential by FY 2002. About 1,100 scientists and students from 90 institutions and 19 countries participate in the RHIC research program. These four detectors (described in the Site Descriptions) provide complementary measurements, but with some overlap in order to cross-calibrate the measurements.

▪ **Other Operations**	**15,585**	**17,496**	**14,360**

As steward for Brookhaven National Laboratory (BNL), the Nuclear Physics program provides General Plant Project (GPP), General Purpose Equipment (GPE) and other funding for minor new construction, other capital alterations and additions, and for buildings and utility system, for needed laboratory equipment and other expenses. 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. In FY 2003 funding for GPP remains at the same level as FY 2002 while GPE and other costs are reduced.

Total, Heavy Ion Nuclear Physics	**152,112**	**155,618**	**167,977**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Research	
▪ **University Research**	
▸ FY 2003 funding for grants for University Research increases by 2.2%, maintaining a comparable effort to FY 2002. Lower priority activities will be reduced in order to focus efforts on those activities at RHIC identified as providing the most promising physics opportunities.	+245
▪ **National Laboratory Research**	
▸ **BNL RHIC Research:** Research support is increased by $100,000 (1.6%) to effectively carry out research with the enhanced detectors at full luminosity at RHIC. Capital equipment is decreased by $1,012,000.	- 912
▸ **Other National Laboratory Research:** Research support for operations is increased by $638,000 (7.0%) to enhance effort compared to FY 2002. Capital equipment increases by $1,144,000 compared with FY 2002.	+1,782
Total, National Laboratory Research	+870

	FY 2003 vs. FY 2002 ($000)
▪ **Other Research:**	
▸ Estimated SBIR and other obligations increase.	+388
Total, Research	+1,503
Operations	
▪ **RHIC Operations**	
▸ **Accelerator Operations:** An increase of $10,205,000 (+14.0%) in operating funds provides an estimated 3,300 hours for research, providing 1,650 hours more than in FY 2002. An increase of $400,000 is provided for Accelerator Improvement Project funding (to a total of $2,900,000) to a level that can sustain operations.	+10,605
▸ **Experimental Support:** Funding is increased by $2,290,000 (+9.5%) compared to FY 2002. An increase of $1,097,000 is provided in capital equipment to support operations at full luminosity.	+3,387
Total, RHIC Operations	+13,992
▪ **Other Operations**	
▸ FY 2003 funding for General Plant Projects to Brookhaven National Laboratory is approximately constant compared with FY 2002. Funding for General Plant Equipment decreases by $972,000. Other operations decrease by $2,164,000 compared with FY 2002	-3,136
Total, Operations	+10,856
Total Funding Change, Heavy Ion Nuclear Physics	+12,359

Low Energy Nuclear Physics

Mission Supporting Goals and Objectives

The Low Energy Nuclear Physics subprogram supports research directed at understanding the structure of nuclei, nuclear reaction mechanisms, and experimental tests of fundamental symmetries, including neutrino oscillations. The forefront of nuclear structure research lies in studies of nuclei at the limits of energy, deformation, angular momentum, and isotopic stability. The properties of nuclei at these extremes are not known and such knowledge is needed to test and drive improvement in nuclear models and theories about the nuclear many-body system. Knowledge of the detailed nuclear structure, nuclear reaction rates, half-lives of specific nuclei, and the limits of nuclear existence at both the proton and neutron drip lines is crucial for understanding the nuclear astrophysics processes responsible for the production of the chemical elements in the universe, and the explosive dynamics of supernovae. Progress in both nuclear structure and astrophysics studies depend upon the availability of exotic beams, or beams of short-lived nuclei, to produce and study nuclei that lie in unstudied regions of the nuclear chart and that are involved in important astrophysics processes. While the U.S. today has facilities with limited capabilities for these studies, it was already noted in the 1996 NSAC Long Range Plan for Nuclear Science that a facility with next generation capabilities for short-lived radioactive beams will be needed in the future for the U.S. to maintain a leadership role. In FY 1999 a NSAC Taskforce established the optimal technical option for such a facility, the Rare Isotope Accelerator (RIA) facility. The ongoing 2001 NSAC long-range planning process is identifying RIA as the highest priority for a major new construction project. Starting in FY 2000, R&D activities have been supported in preparation for a request for approval for construction. Continued pre-conceptual funding for these R&D activities is supported in FY 2003.

The research of this subprogram is generally conducted using beams provided by accelerator facilities either operated by this subprogram or at other domestic or foreign facilities. The Low Energy Nuclear Physics subprogram supports the operation of three national user facilities: the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory, the Argonne Tandem Linac Accelerator System (ATLAS) facility at Argonne National Laboratory, and the 88-Inch Cyclotron facility at the Lawrence Berkeley National Laboratory. These 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 equipment facilities to maintain and improve the reliability and efficiency of operations, and to provide new accelerator capabilities.

University-based research is an important feature of the Low Energy subprogram. Accelerator operations are supported at Texas A&M University (TAMU), the Triangle Universities Nuclear Laboratory (TUNL), University of Washington, and Yale University. Each of these university centers of excellence has a critical mass of nuclear physics faculty involved in research that is conducted both on and off campus, about 15-25 graduate students at different stages of their education, and historically has produced a large fraction of the leaders in the 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.

The Low Energy subprogram also supports studies of fundamental interactions and symmetries in selected nuclei, "laboratories" that allow exquisite measurements to test the present understanding of the Standard Model. Some experiments use accelerators in conjunction with special apparatus to study fundamental nuclear and nucleon properties, as for example the ultra-cold neutron trap at the Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory. Other experiments in low energy nuclear physics do not require the use of accelerators. The study of neutrinos from the sun is an example. The Sudbury Neutrino Observatory (SNO) detector is studying the production rate and properties of solar neutrinos. The Kamioka Large Anti-Neutrino Detector (KamLAND) will study the properties of anti-neutrinos produced by nuclear power reactors. Both of these experiments address the important and interesting question of whether neutrinos have a mass. The answer to this very fundamental question has profound implications for our understanding of the basic building blocks of matter and the evolution of the universe, and the dynamics of "core collapse" supernovae.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Research					
University Research	17,856	16,849	17,591	+742	+4.4%
National Laboratory Research	20,017	19,883	20,044	+161	+0.8%
Other Research	3,044	3,830	4,743	+913	+23.8%
Subtotal Research	40,917	40,562	42,378	+1,816	+4.5%
Operations	21,733	21,860	23,780	+1,920	+8.8%
Total, Low Energy Nuclear Physics	62,650	62,422	66,158	+3,736	+6.0%

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
Research	**40,917**	**40,562**	**42,378**
▪ **University Research**	**17,856**	**16,849**	**17,591**

Support is provided for the research of 140 scientists and 90 graduate students at 29 universities in 21 states. Nuclear Physics university scientists perform research as user groups at National Laboratory facilities, at on-site facilities and at other specifically fabricated experiments. These activities address a broad range of fundamental issues as diverse as the properties of nuclei, the nature of the weak interaction and the production mechanisms of the chemical elements in stars and supernovae. FY 2003 funding for university accelerator facilities, and for researchers and students is increased by ~3.6% compared to FY 2002. Funding for capital equipment projects is increased by $189,000. Research activities include:

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

- Research programs conducted using the low energy heavy-ion beams and specialized instrumentation at the national laboratory user facilities supported by this subprogram (the ANL-ATLAS, LBNL – 88-Inch Cyclotron and ORNL – HRIBF facilities). The effort at the user facilities involves about two-thirds of the university scientists supported by this subprogram.
- Accelerator operations at four universities: the University of Washington, the Triangle Universities Nuclear Laboratory (TUNL) facility at Duke University, Texas A&M University (TAMU) and at Yale University. Each of these small university facilities has a well-defined and unique physics program, providing light and heavy ion beams, specialized instrumentation and opportunities for long-term measurements which complement the capabilities of the National Laboratory user facilities. Equipment funds are provided for new instruments and capabilities, including an energy and intensity upgrade to the High Intensity Gamma-ray Source (HIγS) facility at TUNL.
- Involvement in other accelerator and non-accelerator experiments directed at fundamental measurements, such as measurements of solar neutrino rates and the neutrino mass at the Sudbury Neutrino Observatory (SNO) in Canada. The U.S. effort with the Kamioka Large Anti-Neutrino Detector (KamLAND) in Japan, is being supported jointly with the High Energy Physics program.

	FY 2001	FY 2002	FY 2003
▪ **National Laboratory Research**	**20,017**	**19,883**	**20,044**

Support is provided for the research programs of scientists at six National Laboratories (ANL, BNL, LBNL, LANL, LLNL and ORNL).

	FY 2001	FY 2002	FY 2003
► **National Laboratory User Facility Research**	**14,394**	**13,851**	**14,455**

Scientists at ANL, LBNL, and ORNL have major responsibilities for maintaining, improving and developing instrumentation for research by the user communities at the user facilities, as well as playing important roles in carrying out research that addresses the program's priorities. In FY 2002 the three user facilities support the following research activities:

– At ORNL the research focuses on the use of radioactive beams from the HRIBF and specialized spectrometers to study the nuclear structure of nuclei far from stability. Measurements are made of reaction cross sections and nuclear properties, such as half-lives, which are crucial input to detailed astrophysics models that calculate the production of the elements in stars. Specialized equipment is employed, such as a system that integrates gamma-ray and charged-particle detectors with a recoil mass separator. The high-pressure gas target for nuclear astrophysics experiments has been built, and is undergoing commissioning and initiating its first experiments.

– At ANL the research focuses on the use of stable and selected radioactive beams from ATLAS, coupled to ion traps and the Fragment Mass Analyzer to study fundamental processes and properties of nuclei, and to study nuclei at the extremes of isotope stability. Studies are undertaken with traps to measure atomic masses with high precision and search for effects in beta decay outside the standard decay model. The Advanced Penning Trap is being commissioned and tested.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

– At LBNL the research focuses on the use of stable beams from the 88-Inch Cyclotron with Gammasphere and the Berkeley Gas-filled Spectrometer (BGS) to study nuclei at high angular momentum and deformation, and the heaviest of elements. The world-leading effort to search for and characterize new very heavy elements and isotopes will continue. Conceptual design of a high-sensitivity gamma-ray tracking detector, 1000 times more sensitive than Gammasphere, is continuing. Test modules, electronics and data analysis algorithms are undergoing development.

▸ **Other National Laboratory Research**........................	**5,623**	**6,032**	**5,589**

Scientists at BNL, LBNL, LLNL and LANL play important roles in a number of high-priority accelerator- and non-accelerator-based experiments directed towards fundamental questions. These include:

– The Sudbury Neutrino Observatory (SNO) experiment in Canada. The SNO detector, jointly built by Canada, England and the U.S., addresses the question of whether the observed reduced rate of solar neutrinos reaching the earth results from unexpected properties of the sun, or whether it results from a fundamental property of neutrinos–namely that neutrinos produced in the sun change their nature (that is, oscillate to a new neutrino type) during the time it takes them to reach the earth. This latter explanation would imply that the neutrinos have mass. In FY 2001, the first results from SNO were reported, indicating strong evidence for neutrino oscillations. In FY 2001, the second phase of the SNO experiment began. This phase measures neutrino types to which the solar neutrino have been transformed; preliminary results from this phase are possible in late FY 2002.

– The KamLAND experiment in Japan will measure the rate and properties of anti-neutrinos produced by several distant nuclear power reactors in an attempt to establish and measure the mass of the neutrino. Although KamLAND is less sensitive than SNO to the variety of neutrino oscillations it has the advantage of comparing the measured fluxes to known sources. **Performance will be measured** by the collection of first data with the KamLAND detector in FY 2003.

– Neutron beams at the LANSCE facility at LANL are "cooled" to very low energies for new cold and ultra-cold neutron experiments, which will allow very precise measurements of fundamental neutron properties.

■ **Other Research**..	**3,044**	**3,830**	**4,743**
▸ **RIA R&D Activities**...	**2,844**	**2,800**	**3,500**

Funds are provided for R&D and pre-conceptual design activities directed at the development of an advanced Rare Isotope Accelerator (RIA) facility. A next-generation facility for beams of short-lived, radioactive nuclei for nuclear structure, reaction and astrophysics studies is identified in the 2001 Nuclear Science Advisory Committee (NSAC) Long Range Plan as a compelling scientific opportunity and as the highest priority for new construction. The proposed RIA facility is a new paradigm for producing intense beams of very short-lived nuclei that emerged from the 1998 NSAC Taskforce study involving international experts. This facility would position the U.S. to play a leadership role in an area of study with the potential for new discoveries about basic properties of nuclei and to significantly advance our understanding of astrophysical

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

phenomena. The increased funding for FY 2003 supports some of the needed R&D activities in both critical accelerator components and detector development. **Performance will be measured** by the demonstration of the fast ion gas catcher at full beam energy, a critical capability for RIA.

▸ **SBIR and Other**	**200**	**1,030**	**1,243**

In FY 2001 $639,000 was transferred to the SBIR program. This section includes $655,000 for SBIR in FY 2002 and $868,000 for SBIR in FY 2003 and other established obligations. The Lawrence and Fermi Awards, funded under this line, provide annual monetary awards to honorees selected by the Department of Energy for their outstanding contributions to science.

Operations	**21,733**	**21,860**	**23,780**

Support has been provided for the operation of three National User Facilities, the Argonne Tandem-Linac Accelerator System (ATLAS) at ANL, the 88-Inch Cyclotron facility at LBNL and the Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL, for studies of nuclear reactions, structure and fundamental interactions.

HRIBF has coupled the existing cyclotron and tandem accelerator to develop a focused radioactive-ion beam program. Both proton-rich and neutron-rich beams are provided to spectrometer systems such as CHARMS, designed for nuclear structure studies, and the Daresbury Recoil Separator and the Silicon Detector Array for nuclear astrophysics studies.

ATLAS provides stable heavy-ion beams and selected radioactive-ion beams for research. Experiments utilize ion traps, the Fragment Mass Analyzer, and advanced detectors to study the structure of nuclei at the limits of stability, and fundamental and decay properties of nuclei.

The 88-Inch Cyclotron facility provides primarily stable heavy-ion beams for research. Gammasphere and the Berkeley Gas-filled Spectrometer provide world-class instruments to study rapidly spinning nuclei, and search for and characterize the heaviest of elements and isotopes. An innovative BEARS (Berkeley Experiments with Accelerated Radioactive Species) system has been developed to provide selected light radioactive-ion beams for experiments.

Included in the funding shown are Capital Equipment and Accelerator Improvement Project (AIP) funds provided to each of the operating facilities for the enhancement of the accelerator systems and experimental equipment.

In FY 2003 these low energy facilities will carry out about 100 experiments involving over 360 U.S. and foreign researchers. Planned beam hours for research are indicated below:

	(hours of beam for research)		
	FY 2001	FY 2002	FY 2003
Total beam hours for research	12,175	9,500	10,500

Total, Low Energy Nuclear Physics	**62,650**	**62,422**	**66,158**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Research	
▪ **University Research**	
▸ FY 2003 funding for researchers and students is increased by 3.6% from FY 2002. Priority will be given to effectively operating the university accelerator facilities, utilizing the national user facilities, and supporting those activities where recent investments have been made, such as SNO and KamLAND. Funding for equipment also increases by $189,000 compared to FY 2002 with the continuation of the HIγS (High Intensity Gamma Source) upgrade at TUNL.	+742
▪ **National Laboratory Research**	
▸ **National User Facilities Research:** FY 2003 funding provides an increase of about 4.4% to enhance research efforts and activities at the three user facilities.	+604
▸ **Other National Laboratory Research**: Research funding is about constant compared to FY 2002. Manpower and effort will be focused on the high priority activities at the national user facilities, SNO and KamLAND. Equipment funds are reduced by $454,000 as projects are completed with no new starts.	-443
Total, National Laboratory Research	+161
▪ **Other Research**	
▸ **RIA R&D:** In FY 2003 $3,500,000 is provided for R&D activities directed at the development of an advanced Rare Isotope Accelerator (RIA) facility. The R&D funding is directed at projects identified in a 3-year R&D plan that has been developed for work that will be performed at ANL, LANL, LBNL, LLNL, ORNL, TJNAF and Michigan State University.	+700
▸ **SBIR and Other:** Estimated SBIR and other obligations increase slightly.	+213
Total, Other Research	+913
Total Research	+1,816
Operations	
▪ In FY 2003 operations are increased by 8.8% compared to FY 2002 to operate the three user facilities providing an increase in an estimated 1,000 hours of beam time for research. Funding for capital equipment and accelerator improvement projects to support these operations increases by $70,000 (+1.7%).	+1,920
Total Funding Change, Low Energy Nuclear Physics	+3,736

Nuclear Theory

Mission Supporting Goals and Objectives

Progress in nuclear physics, as in any science, depends critically on improvements in the theoretical techniques and on the development of new insights that will lead to a theoretical foundation that can be used to predict and interpret experimental results. The goal of the Nuclear Theory subprogram is to make such progress in understanding the characteristics of atomic nuclei and nuclear matter and the fundamental forces involved, utilizing the new results that come from the experimental programs discussed previously and new capabilities that become available.

There are three major frontiers in nuclear theory today. The first involves understanding the properties and behavior of nuclei. In the past, significant progress had been made from the development of theoretical models that view nuclei as interacting ensembles of protons and neutrons. This paradigm of the nucleus is now being revolutionized as new calculational and conceptual tools are being developed which permit microscopic calculations that previously had not been possible. Similarly, collective models, in which the nucleus is treated as a drop of fluid or in which pairs of neutrons or protons are treated as single particles, have achieved great success in describing many aspects of nuclear behavior too complicated to treat with protons and neutrons. With the possibility of new experimental results for nuclei far from stability from studies with radioactive beams, there is hope for developing a “standard model” for nuclei that is applicable across the periodic table. With the establishment of Quantum ChromoDynamics as the fundamental theory of the strong nuclear interaction, a second frontier of nuclear theory is to understand nuclei and the nucleon in terms of their constituent quarks and gluons. This goal is pursued through scientific investigations at the Thomas Jefferson National Accelerator Facility (TJNAF). The third major frontier of nuclear theory is to understand the properties of hot, dense nuclear matter, the central topic of research at the Relativistic Heavy Ion Collider (RHIC). Various approaches from nuclear theory have recently been applied to nuclear astrophysics topics such as supernova explosions, nucleosyntheses of the elements, and properties of neutrinos from the sun, as well as topics from fundamental symmetry investigations.

The Nuclear Theory subprogram supports research 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. 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 that includes experimentalists. The Institute is a seedbed for new collaborations, ideas, and directions in nuclear physics.

The program is greatly enhanced through interactions with complementary programs overseas, with efforts supported by the National Science Foundation, with programs supported by the High Energy Physics program and with the Japanese supported theoretical efforts related to RHIC at Brookhaven National Laboratory. Many foreign theorists participate on advisory groups as peer reviewers. There is large participation in the INT by researchers from Europe and Japan and by researchers in overlapping fields such as astrophysics, atomic and molecular physics and particle physics.

Included in this subprogram are the activities that are aimed at providing information services on critical nuclear data and have as a goal the compilation and dissemination of an accurate and complete nuclear data information base that is readily accessible and user oriented.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Theory Research					
University Research	11,797	10,475	11,045	+570	+5.4%
National Laboratory Research	6,948	8,120	8,590	+470	+5.8%
Subtotal Theory Research	18,745	18,595	19,635	+1,040	+5.6%
Nuclear Data Activities	4,877	4,890	5,010	+120	+2.5%
Total, Nuclear Theory	23,622	23,485	24,645	+1,160	+4.9%

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
Theory Research	**18,745**	**18,595**	**19,635**
▪ **University Research**	**11,797**	**10,475**	**11,045**

The research of about 160 university scientists and 85 graduate students is supported through 54 grants at 41 universities in 25 States and the District of Columbia. The range of topics studied is broad, constantly evolving, and each active area of experimental nuclear physics is supported by nuclear theory activities. Graduate student and postdoc support is a major element of this program.

The Institute for Nuclear Theory (INT) at the University of Washington hosts three programs per year where researchers from around the world attend to focus on specific topics or questions. These programs result in new ideas and approaches, the formation of collaborations to attack specific problems and the opportunity for interactions of researchers from different fields of study. For example, recent programs have resulted in a new research effort that fuses modern shell model technology with effective field theory to potentially provide a tractable, rigorous solution for low-energy properties of nuclei.

	FY 2001	FY 2002	FY 2003
▪ **National Laboratory Research**	**6,948**	**8,120**	**8,590**

Research programs are supported at six National Laboratories (ANL, BNL, LANL, LBNL, ORNL and TJNAF).

- 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.
- In all cases, the nuclear theory research at a given laboratory provides support to the experimental programs at that laboratory, or takes advantage of some unique facilities or 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.

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		

- Funding is provided for new activities to model and calculate complex astrophysical nuclear processes, for example, in stellar supernovae explosions, and the quark/gluon-based structure of nuclei using "lattice gauge" techniques. Both efforts require investments in new computational modeling and simulation research and show great promise in pushing our understanding of the physics of these disciplines to new levels.

	FY 2001	FY 2002	FY 2003
Nuclear Data	**4,877**	**4,890**	**5,010**

The Nuclear Data program collects, evaluates, archives, and disseminates information on nuclear properties and reaction processes for the community and the nation. The focal point for its national and international activities is at the DOE-managed National Nuclear Data Center (NNDC) at Brookhaven National Laboratory.

The NNDC relies on the U.S. Nuclear Data Network (USNDN), a network of DOE supported individual nuclear data professionals located in universities and at other National Laboratories who perform data assessment as well as developing modern network dissemination capabilities.

The NNDC participates in the International Data Committee of the International Atomic Energy Agency (IAEA).

	FY 2001	FY 2002	FY 2003
Total, Nuclear Theory	**23,622**	**23,485**	**24,645**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
University Research	
▸ FY 2003 funding level is increased by 5.4 % compared to FY 2002. This provides increased funding for students and focused funding for priority targeted research.	+ 570
National Laboratory Research	
▸ FY 2003 funding level is increased by 5.8% compared to FY 2002. This will permit retention of productive researchers in existing groups and a minimal expansion of priority targeted research.	+ 470
Nuclear Data	
▸ FY 2003 funding level is increased by 2.5% compared to FY 2002. Lower priority activities will be phased out in order to maintain manpower in the higher priority activities.	+120
Total Funding Change, Nuclear Theory	+1,160

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
General Plant Projects	7,104	6,439	6,560	+121	+1.9%
Accelerator Improvement Projects	5,419	5,450	5,400	-50	-0.9%
Capital Equipment	31,505	30,162	30,220	+58	+0.2%
Total, Capital Operating Expenses	44,028	42,051	42,180	+129	+0.3%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp- riations	FY 2001	FY 2002	FY 2003 Request	Accept- ance Date
PHENIX Muon Arm Instrumentation	12,897	11,535	1,362	0	0	FY 2002
BLAST Large Acceptance Detector	5,200	4,000	1,200	0	0	FY 2001
STAR EM Calorimeter	8,600	2,100	2,897	3,000	603	FY 2003
STAR EM Calorimeter Enhancement	4,700	0	0	0	2,400	FY 2004
G0 Experiment Detector	3,965	2,890	1,016	59	0	FY 2002
Total, Major Items of Equipment		20,525	6,475	3,059	3,003	

Advanced Scientific Computing Research

Program Mission

The mission of the Advanced Scientific Computing Research (ASCR) program is to foster and support fundamental research in advanced scientific computing – applied mathematics, computer science, and networking and provide the high performance computational and networking tools that enable DOE to succeed in its science, energy, environmental quality, and national security missions. The importance of advanced scientific computing to the missions of the Department was clearly stated in the "Scientific Discovery through Advanced Computing," (SciDAC) report, which was delivered to Congress in March 2001:

> *"Advanced scientific computing is key to accomplishing the missions of the U.S. Department of Energy (DOE). It is essential to the design of nuclear weapons, the development of new energy technologies, and the discovery of new scientific knowledge. All of the research programs in DOE's Office of Science … have identified major scientific questions that can only be addressed through advances in scientific computing."*

Strategic Objectives

SC5: To enable advances and discoveries in DOE science through world-class research in applied mathematics, computer sciences, networks and computational sciences and through the distributed operation of high performance, scientific computing and network facilities; and to deliver, in FY 2006, a suite of specialized software tools for DOE scientific simulations that take full advantage of terascale computers and high speed networks.

SC7-5: Provide major advanced scientific user facilities where scientific excellence is validated by external review; average operational downtime does not exceed 10% of schedule; construction and upgrades are within 10% of schedule and budget; and facility technology research and development programs meet their goals.

Program Strategic Performance Goals and Targets

SC5-1: Build leading research programs in focused disciplines of applied mathematics, computer science, and network and collaboratory research important to national and energy security to spur revolutionary advances in the use of high performance computers and networks. (Mathematical, Information and Computational Sciences subprogram)

Performance Indicator

Invited presentations at major national and international conferences.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Initiated project to understand the advantages and issues associated with lightweight kernel operating systems rather than full kernels for the compute nodes of extreme-scale scientific computers. [Met Goal]	Complete the development of the Cougar lightweight kernel for clusters of Alpha processor-based computers and begin the assessment of scalability and performance for selected applications. (SC5-1)	Complete the definitive analysis of the advantages and issues associated with lightweight kernel operating systems rather than full kernels for the compute nodes of extreme-scale scientific computers, resolving a critical issue for the future of high performance computers in the U.S. (SC5-1)
Supported the Computational Science Graduate Fellowship Program with the successful appointment of 20 new students to support the next generation of leaders in computational science for DOE and the Nation. [Met Goal]	Appoint 20 new students to the Computational Science Graduate Fellowship Program to develop the next generation of leaders in computational science for DOE and the Nation. (SC5-1)	Appoint 20 new students to the Computational Science Graduate Fellowship Program to develop the next generation of leaders in computational science for DOE and the Nation. (SC5-1)

SC5-2: Create the *Mathematical and Computing Systems Software* and the *High Performance Computing Facilities* that enable Scientific Simulation and Modeling Codes to take full advantage of the extraordinary capabilities of terascale computers, and the *Collaboratory Software Infrastructure* to enable geographically-separated scientists to effectively work together as a team as well as provide electronic access to both facilities and data. (Mathematical, Information and Computational Sciences subprogram)

Performance Indicator

Software released to applications teams.

Performance Standards

As discussed in the Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Operated facilities, including the National Energy Research Scientific Computing Center (NERSC) and ESnet, within budget while meeting user needs and satisfying overall SC program requirements where, specifically, NERSC delivered 3.6 Teraflop capability at the end of FY 2001 to support DOE's science mission. [Exceeded Goal]	Achieve operation of the IBM-SP computer at 5.0 Teraflop "peak" performance. These computational resources will be integrated by a common high performance file storage system that facilitates interdisciplinary collaborations. (SC5-2) Migrate the users with the largest allocations to the IBM-SP from the previous generation Cray T3E. (SC5-2)	Begin installation of next generation NERSC computer, NERSC-4, that will quadruple the capability available to solve leading edge scientific problems. (SC5-2)
		Initiate at least 8 competitively selected interdisciplinary research teams to provide computational science and applied mathematics advances that will accelerate biological discovery in microbial systems and develop the next generation of computational tools required for nanoscale science based on peer review, in partnership with the Biological and Environmental Research and Basic Energy Sciences programs, respectively, of submitted proposals. (SC5-2)

SC7-5: Provide advanced scientific user facilities where scientific excellence is validated by external review; average operational downtime does not exceed 10% of schedule; construction and upgrades are within 10% of schedule and budget; and facility technology research and development programs meet their goals. (Mathematical, Information and Computational Sciences subprogram)

Performance Indicator

Percent unscheduled downtime.

Performance Standards

As discussed in the Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Maintained and operated facilities, including NERSC and ESnet, so the unscheduled downtime on average is less than 10 percent of the total scheduled operating time. [Met Goal]	Maintain and operate facilities, including NERSC and ESnet, so the unscheduled downtime on average is less than 10 percent of the total scheduled operating time. (SC7-5)	Maintain and operate facilities, including NERSC and ESnet, so the unscheduled downtime on average is less than 10 percent of the total scheduled operating time. (SC7-5)
Initiated the review of ASCR high performance computing facilities by the Advanced Scientific Computing Advisory Committee (ASCAC). [Met Goal]	Deliver preliminary report of ASCAC review of ASCR high performance computing facilities. (SC7-5)	Complete the review of ASCR high performance computing facilities by the Advanced Scientific Computing Advisory Committee (ASCAC) and implement action plans to respond to recommendations. (SC7-5)

Significant Accomplishments and Program Shifts

The major thrust of the research efforts supported by the ASCR program is to establish the mathematics and computer science foundations and develop the specialized software tools needed to effectively utilize rapidly-evolving, high-performance computing and networking hardware to enable new scientific discoveries across the research portfolio of the Office of Science. Advances in microelectronics continue to fuel dramatic performance improvements in computing and networking technologies. However, commercial market needs and expectations, which are driving those improvements, are dramatically different from the needs and the expectations of the researchers being supported to advance DOE science. Consequently, the DOE and other Federal agencies whose missions depend on high-performance, scientific computing, must make research investments to adapt high-performance computing and networking hardware into tools for scientific discovery. The importance of these tools to the DOE Office of Science mission and the fundamental differences between business, personal and scientific requirements are illustrated by the following examples:

- Intermetallic compounds, such as iron-manganese-cobalt (Fe-Mn-Co), have properties that would be attractive in a wide variety of applications including, transportation, data storage and computer read/write heads. Before many of these applications can be realized, an important fundamental feature to understand is the degree of "exchange bias," which is responsible for the novel magnetic properties of these materials. Scientifically, the "exchange bias" arises when an antiferromagnetic layer such as FeMn pins the orientation of the magnetic moment of an adjacent ferromagnetic layer such as Cobalt. A calculation performed during the summer of 2001 showed, for the first time, that the magnetic structure of the FeMn layer adjacent to the cobalt layer of atoms was fundamentally different from the magnetic structure of pure FeMn material. This dramatic discovery provides important scientific insight into the properties of magnetic materials and suggests that the "design" of materials with unusual magnetic properties may be fostered through supercomputer simulations. Here are some features of the calculation:
  - The researchers performed a simulation of two layers of Fe-Mn-Co containing 2,016 atoms. (About 15,000 atoms would be needed to accurately model all features of this intermetallic material.) In order to predict the magnetic behavior in the interface region, approximately 30 trillion operations (i.e. additions, subtractions, multiplications and divisions) are required for each atom. Furthermore, 48 megabytes (MB) of memory were needed to store critical

data for each atom. The entire calculation required approximately 100 gigabytes (GB) of memory and 60 quadrillion (60×10^{15}) operations to complete.

  - To put this in context, a 1GHz desktop workstation would need its memory upgraded by a factor of 1500 to perform this calculation, which would take one year to finish. A more realistic comparison can be made by comparing a run on NERSC-3 with a run on a previous generation supercomputer a Cray T3E (NERSC-2). Using 644 processors on the T3E, the code ran at 347 Gflops and required 2 days to complete. Using 2176 processors on the IBM-SP (NERSC-3) the code achieved 2460 Gflops and required only 6.6 hours to complete.

- Scientific simulations to meet Office of Science missions frequently involve accessing large data files on the order of millions to billions of megabytes (MB) in size. These data files are being generated by measurements, experiments, and simulations at many locations around the world. Reliable access to these data requires investments in high-speed high-bandwidth networks, and in robust, efficient network software. To highlight the special features of these requirements, the supercomputing conference series initiated a Network Bandwidth Challenge in 2000, in which researchers were invited to demonstrate their ability to maximize network performance for their application. In both 2000 and 2001, the first prize for optimal use of the network went to a DOE laboratory-led application. In 2001, the prize-winning application was based on an interactive, scientific simulation running at two separate supercomputers. The results of the simulation were sent to the conference floor over the network and visualized at a sustained network performance level of 3.3 gigabits per second, or approximately 1,000 times faster than commercially available DSL.

- A national consortium of climate scientists, computer scientists and applied mathematicians, including DOE researchers, is developing the Coupled Parallel Climate Model (PCM), a terascale simulation code to assist the U.S. National Assessment effort in global climate change. The PCM code is unique in combining atmospheric, ocean, and sea-ice models into a tightly coupled terascale simulation. The PCM code must be run many times with varying assumptions on environmental conditions to create an ensemble of results that, in the aggregate, provides the capability of predicting trends in global climate change. Today's largest supercomputers and software tools can reliably produce results with about 300 km resolution, which is adequate for simulating global effects, such as the jet stream and the temperature profile of the earth. Next generation supercomputer hardware and software tools will be required to perform simulations on a 50 km resolution or less. This will allow accurate simulation of regional effects, such as complex topography and the influence of rivers and streams.

The ASCR program builds on several decades of leadership in high performance computing and many pioneering accomplishments, such as the establishment of the first national supercomputer center in 1974. The principles that guide the integration of these efforts will be discussed in more detail in the MICS subprogram narrative. Building on this long history, principal investigators have received recognition through numerous prizes, awards, and honors. A list of FY 2001 accomplishments and awards is given below.

ACCOMPLISHMENTS

Mathematical, Information and Computational Sciences

- *Babel Language Interoperability: Component Technology for Scientific Software.* Computer scientists at Lawrence Livermore National Laboratory, in collaboration with members of the Common Component Architecture working group, have developed a language interoperability tool that supports the re-use of scientific libraries across multiple programming languages that are prevalent in high end applications. Previously, application developers often could not re-use existing software libraries if the library and the application were written in different programming languages. Using LLNL's language interoperability tool, called Babel, library writers may now deliver libraries that can be called from any of the standard scientific languages, including Fortran 77, C, C++, and Python. Support for Java and Fortran 90 is under development.

- *Hypre: Conceptual Interfaces Provide Access to State-of-the-art Linear Solvers.* A valuable new approach for describing linear systems of equations to linear solver libraries can be described as so-called “physics-based” or “conceptual” interfaces. Unlike traditional matrix-based interfaces used in most libraries, conceptual interfaces are more natural for application users and provide the additional information (e.g., the description of a computational grid) necessary for exploiting powerful linear solver algorithms such as geometric multigrid. Researchers at the Lawrence Livermore National Laboratory, for the first time, developed a Fast Adaptive Composite algorithm through a stand alone linear solver library, eliminating the need for users to “roll their own,” as is the case presently. As a bonus, this interface also provides access to standard matrix-based solvers such as Incomplete Factorizations (ILU), Sparse Approximate Inverse methods, and Algebraic Multigrid (AMG), without requiring user code changes.

- *Pushing Collaboration beyond the Desktop.* Researchers at the Argonne National Laboratory continue to push technology to enable scientific collaborations with the Access Grid. The Access Grid is the ensemble of resources that can be used to support group-to-group human interaction across the grid. It consists of multimedia display, presentation and interactions environments, interfaces to grid middleware, and interfaces to visualization environments; and it supports large-scale distributed meetings, collaborative work sessions, seminars, lectures, tutorials and training. More than fifty Access Grid "nodes" -- including cameras, microphones and speakers, and multiple computers for audio and video -- have been installed worldwide.

- Novel Computer Interface and Visualization Environment Transferred to Industry. The 3D human-computer interface and visualization environment known as FLIGHT developed by researchers at the Sandia National Laboratories has been commercialized by Novint Technologies. This software represents several “firsts:”

  - First effort to integrate the sense of touch, with real-time graphics interaction.
  - First human interface totally based on 3D interaction tools. Three patents have been submitted.
  - First Trans-Atlantic virtual collaborative environment to interact with force feedback immersively. This work was presented as an invited application at the 2^{nd} International Grid booth at INET’2000.

- *A Lucky Catch: The Oldest, Most Distant Type Ia Supernova Confirmed by Supercomputer Analysis at NERSC.* An exploding star dubbed SN 1997ff, caught once on purpose and twice by accident by NASA's Hubble Space Telescope, is the oldest and most distant Type Ia supernova ever seen, according to a recent analysis performed at the Department of Energy's National Energy Research Scientific Computing Center (NERSC) at Lawrence Berkeley National Laboratory. Scientists from the Lawrence Berkeley National Laboratory and the Space Telescope Science Institute that studied the distant supernova, used an IBM SP supercomputer to perform the analysis at NERSC, a world-class, 5 Teraflop, unclassified supercomputing center. By digitally subtracting images from the same region of space taken on two different dates, the researchers were able to isolate a supernova event and unravel much of the uncertainty associated with the observed data. As a result of their simulations, these researchers determined that the supernova was of Type Ia at a redshift of 1.7, and was first observed eight days after it exploded.

- *Fast Visualization of Vector Fields Using Color Mapping.* Researchers at the Sandia National Laboratory have developed two new techniques for visualizing two-dimensional vector fields that use color mapping to depict the flow direction. These approaches are fast because unlike conventional flow visualization techniques such as streamlines, they are completely local and require very little computation. This is especially significant for very large data sets where detection of small complex features is desired in real time. These approaches use the viewer's inherent ability to recognize and understand complex color patterns.
- *Twelve Companies Adopt Argonne Lab/USC Globus ToolkitTM as Standard Grid Technology Platform.* The open source Globus Toolkit^{TM} developed by USC's Information Sciences Institute (ISI) and Argonne National Laboratory has become the de-facto international standard in the burgeoning field of grid computing as twelve leading computer vendors and software providers in the U.S. and Japan announced in November 2001, that they will port and/or support the product. Grid computing is a technology that uses the Internet as basic wiring to let people share computing, storage, data, programs, and other resources, just like the electric power grid allows people and energy companies to share generators of all kinds. The goal is to allow anyone with a computer to effectively integrate instruments, displays, and computational and information resources over a variety of computer platforms.
- *NERSC completes acquisition of new supercomputer.* The Department of Energy's National Energy Research Scientific Computing (NERSC) Center at Lawrence Berkeley National Laboratory has accepted and placed into full service its NERSC-3/Phase 2 system. In June 2001, this 5 Teraflop supercomputer system was number two on the "Top 500" list of the most powerful supercomputers in the world. The system meets, or exceeds, all major, original performance specifications. In FY 2002, its first full year of operation, NERSC-3 will provide the DOE Office of Science research community with 45,000,000 massively parallel processing (MPP) hours for simulations, which is almost a factor of two times the computational capability of the Center one year ago.

AWARDS

Mathematical, Information and Computational Sciences

- *R&D 100 Award.* An R&D 100 award was made to the to the University of Tennessee and Oak Ridge National Laboratory for developing the Performance Application Programming Interface (PAPI). PAPI specifies an application programming interface for accessing hardware performance counters available on most modern microprocessors. PAPI exploits these hardware counters to provide users with precise, high-resolution information on the number and timing of operations performed during software execution, on accesses to the memory hierarchy, on the status of instruction pipelines, and on all the aspects of software execution that must be analyzed when tuning software for high performance.

- *NERSC User Honored by American Physical Society Award for Work in Computational Physics.* Alex Zunger, a physicist at DOE's National Renewable Energy Laboratory in Colorado and a NERSC user, has been named the 2001 recipient of the prestigious Rahman Award by the American Physical Society. The award is presented annually to an individual for "outstanding achievement in computational physics research." Zunger was cited for his "pioneering work on the computational basis for first-principles electronic theory of solids." The Institute for Scientific Information has listed Zunger as one of the most-cited physicists worldwide.
- *Electronic Notebook Recognized for Innovation.* The Electronic Notebook software, enote v1.10, developed by the Oak Ridge National Laboratory and first released in 1999 received an Energy 100 Award in January 2001. These awards recognized the top 100 discoveries and innovations from the Department of Energy that have resulted in improvements for American consumers between 1973 and 2000. Enote provides an easy to use electronic lab notebook that has the look and feel of a scientist's paper notebook, but with additional digital features.

Laboratory Technology Research

- *R&D 100 Award - A New Catalyst Material to Treat Vehicle Exhaust Emissions.* Pacific Northwest National Laboratory (PNNL), in collaboration with Delphi Automotive Systems and Ford Research Laboratory, has developed a zeolite-Y-based-catalyst material for plasma-catalysis engine exhaust treatment that has been shown to remove nearly 90% of Nox, with a cost to fuel efficiency of less than 5%. Unlike other possible catalytic systems, this system is not harmed by sulfur impurities and requires no major design changes to vehicles or fuel infrastructure.
- *Federal Laboratory Consortium (FLC) Award for Excellence in Technology Transfer - Development of High-Temperature Superconducting Wires.* Oak Ridge National Laboratory (ORNL), in collaboration with Minnesota Mining and Manufacturing (3M), has developed a new route to the fabrication of high-temperature superconducting (HTS) wires for high power applications. These HTS materials have tremendous potential for greatly improved energy efficiency in a number of power applications related to the utilization of electrical energy. For example, these materials should produce superconducting transmission lines capable of 2-5 times the power transfer into urban areas, without need for additional rights-of-way and without significant losses to resistance.
- The 2001 Thomas Young Medal and Prize from the Instititute of Physics to a group leader in the Solid State Division of ORNL (awarded in 2001).

PROGRAM SHIFTS

In FY 2003, the MICS subprogram of ASCR will continue its components of the collaborative program across the Office of Science to produce the scientific computing, networking and collaboration tools that DOE researchers will require to address the scientific challenges of the next decade. This program was described in the March 2000 report to Congress entitled, "Scientific Discovery through Advanced Computing," (SciDAC). These activities build on the historic strength of the Department of Energy's Office of Science in computational science, computer science, applied mathematics, and high-performance computing and in the design, development, and management of large scientific and engineering projects and scientific user facilities.

In FY 2003, ASCR will enhance its investments in Advanced Computing Research Testbeds to provide additional specialized capabilities to SciDAC applications research teams that demonstrate significant opportunities for new scientific discovery. The partnership with the Biological and Environmental Research program initiated in FY 2001 in the areas of advanced mathematical, modeling and simulation techniques for biological systems will be expanded. New research will be undertaken to characterize the inventory of multiprotein molecular machines found in a subset of DOE-relevant microbes and organisms with nucleated cells (eukaryotes) and to simulate functional diversity. Results from these investigations are expected to impact clean energy, environmental cleanup, and carbon sequestration efforts. ASCR's contributions to this partnership will consist of developing the underlying mathematical understanding and computational tools that are needed for the analysis and simulation of these biological processes. Finally, in FY 2003, ASCR will initiate a new partnership with the Basic Energy Sciences program in the area of computational nanoscale science, engineering and technology. This partnership is an integral part of the Nanoscale Science, Engineering and Technology initiative in the Office of Science that is led by the Basic Energy Sciences program. The first goal of this initiative is to establish a fundamental scientific understanding of structures and interactions at the nanoscale. For example, it is known that when sample size, grain size, or domain size shrink to the nanoscale, collective phenomena can have a significant influence on local physical properties and may differ dramatically from the corresponding properties in bulk material. The principal missions of the Department of Energy (DOE) in science, energy, defense, and environment will benefit greatly from developments in these areas. Nanoscale synthesis and assembly methods will result in significant improvements in solar energy conversion; more energy-efficient lighting; stronger, lighter materials that will improve efficiency in transportation; greatly improved chemical and biological sensing; use of low-energy chemical pathways to break down toxic substances for environmental remediation and restoration; and better sensors and controls to increase efficiency in manufacturing. ASCR's contributions to this partnership will consist of developing the specialized computational tools for nanoscale science.

A Federally-chartered advisory committee was established for the Advanced Scientific Computing Research program in FY 2000 and is charged with providing advice on: promising future directions for advanced scientific computing research; strategies to couple advanced scientific computing research to other disciplines; and the relationship of the DOE program to other Federal investments in information technology research. This advisory committee will play a key role in evaluating future planning efforts for research and facilities.

Interagency Environment

The research and development activities supported by the MICS subprogram are coordinated with other Federal efforts through the Interagency Principals Group, chaired by the President's Science Advisor, and the Information Technology Working Group (ITWG). The ITWG represents the evolution of an interagency coordination process that began under the 1991 High Performance Computing Act as the High Performance Computing, Communications, and Information Technology (HPCCIT) Committee. DOE has been a key participant in these coordination bodies from the outset and will continue to coordinate its R&D efforts closely through this process.

In FY 1999, the President's Information Technology Advisory Committee (PITAC) recommended significant increases in support of basic research in: Software; Scalable Information Infrastructure; High End Computing; Socio-Economic and Workforce Impacts; support of research projects of broader scope; and visionary “Expeditions to the 21st Century” to explore new ways that computing could benefit our world.

Although the focus of the enhanced DOE program is on solving mission critical problems in scientific computing, this program will make significant contributions to the Nation’s Information Technology Basic Research effort just as previous DOE mission-related research efforts have led to DOE’s leadership in this field. In particular, the MICS subprogram will place emphasis on software research to improve the performance of high-end computing as well as research on the human-computer interface and on information management and analysis techniques needed to enable scientists to manage, analyze and visualize data from their simulations, and develop effective collaboratories. DOE’s program, which focuses on the information technology research needed to enable scientists to solve problems in their disciplines, differs from the National Science Foundation’s portfolio, which covers all of information technology. In addition, DOE’s focus on large teams with responsibility for delivering software that other researchers can rely on differs from NSF’s single investigator focus.

Scientific Facilities Utilization

The ASCR program request includes $28,244,000 in FY 2003 to support the National Energy Research Scientific Computing (NERSC) Center, which is ASCR’s component of the SC-wide Scientific Facilities Initiative that started in FY 1996. This investment will provide computer resources for about 2,400 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 one of the Nation’s premier unclassified computing centers, 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.

Workforce Development

The R&D Workforce Development mission is to ensure the supply of computational and computer science and Ph.D. level scientists for the Department and the Nation through graduate student and postdoctoral research support. In FY 2003, this program will support approximately 800 graduate students and post doctoral investigators, of which 500 will be supported at Office of Science user facilities.

ASCR will continue the Computational Science Graduate Fellowship Program with the successful appointment of 20 new students to support the next generation of leaders in computational science.

Funding Profile

(dollars in thousands)

	FY 2001 Comparable Appropriation	FY 2002 Original Appropriation	FY 2002 Adjustments	FY 2002 Comparable Current Appropriation	FY 2003 Request
Advanced Scientific Computing Research					
Mathematical, Information, and Computational Sciences	151,647	155,050	-650	154,400	166,625
Laboratory Technology Research	9,649	3,000	0	3,000	3,000
Subtotal, Advanced Scientific Computing Research	161,296	158,050	-650	157,400	169,625
General Reduction	0	-650	650	0	0
Total, Advanced Scientific Computing Research	161,296 [a] [b]	157,400	0	157,400	169,625

Public Law Authorization:

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

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

[a] Excludes $3,990,000 which was transferred to the SBIR program and $239,000 which was transferred to the STTR program.

[b] Excludes $225,000 which was transferred to the Science Safeguards and Security program in an FY 2001 reprogramming.

Funding by Site

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	5,727	2,855	5,020	+2,165	+75.8%
Sandia National Laboratories	4,656	4,767	3,889	-878	-18.4%
Total, Albuquerque Operations Office	10,383	7,622	8,909	+1,287	+16.9%
Chicago Operations Office					
Ames Laboratory	2,151	1,991	1,625	-366	-18.4%
Argonne National Laboratory	14,077	11,246	8,573	-2,673	-23.8%
Brookhaven National Laboratory	2,130	1,199	542	-657	-54.8%
Fermi National Accelerator Laboratory	120	226	60	-166	-73.5%
Princeton Plasma Physics Laboratory	190	340	0	-340	--
Chicago Operations Office	28,161	12,060	7,240	-4,820	-40.0%
Total, Chicago Operations Office	46,829	27,062	18,040	-9,022	-33.3%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	65,807	51,325	53,223	+1,898	+3.7%
Lawrence Livermore National Laboratory	4,898	6,587	3,068	-3,519	-53.4%
Stanford Linear Accelerator Center	315	502	234	-268	-53.4%
Oakland Operations Office	4,316	1,781	960	-821	-46.1%
Total, Oakland Operations Office	75,336	60,195	57,485	-2,710	-4.5%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science and Education	349	100	99	-1	-1.0%
Oak Ridge National Laboratory	22,545	11,251	10,496	-755	-6.7%
Thomas Jefferson National Accelerator Facility	50	0	0	0	--
Oak Ridge Operations Office	60	0	0	0	--
Total, Oak Ridge Operations Office	23,004	11,351	10,595	-756	-6.7%
Richland Operations Office					
Pacific Northwest National Laboratory	4,616	3,738	1,003	-2,735	-73.2%
Washington Headquarters	1,128	47,432	73,593	+26,161	+55.2%
Total, Advanced Scientific Computing Research	161,296 [a] [b]	157,400	169,625	+12,225	+7.8%

[a] Excludes $3,990,000 which was transferred to the SBIR program and $239,000 which was transferred to the STTR program.

[b] Excludes $225,000 which was transferred to the Science Safeguards and Security program in an FY 2001 reprogramming.

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 computer science and participates on one of the SciDAC teams. The LTR subprogram at Ames conducts research in the physical, chemical, materials, mathematical, engineering, and environmental sciences through cost-shared collaborations with industry.

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. The MICS subprogram at ANL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. ANL also participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research testbed and participates on a number of the SciDAC teams. The testbed at ANL focuses on a large cluster of Intel-based compute nodes with an open source operating system based on LINUX, this cluster has been given the name of "Chiba City." The LTR subprogram at ANL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are chemistry of ceramic membranes, separations technology, near-frictionless carbon coatings, and advanced methods for magnesium production.

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The MICS subprogram at BNL participates on one of the SciDAC teams. 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 and participates on a number of the SciDAC teams. LBNL manages the Energy Sciences Network (ESnet). ESnet is one of the world's most effective and progressive science-related computer networks that provides worldwide access and communications to Office of Science (SC) facilities. In 1996, the National Energy Research

Scientific Computing Center (NERSC) was moved from the Lawrence Livermore National Laboratory to LBNL. NERSC provides a range of high-performance, state-of-the-art computing resources that are a critical element in the success of many SC research programs. The LTR subprogram at LBNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are molecular lubricants for computers, advanced material deposition systems, screening novel anti-cancer compounds, and innovative membranes for oxygen separation.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on an 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 and participates on a number of the SciDAC teams.

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 and participates on a number of the SciDAC teams.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on 150 acres in Oak Ridge, Tennessee. ORISE provides support for education activities funded within the ASCR program.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The MICS subprogram at ORNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. ORNL also participates in several scientific application and collaboratory pilot projects and participates on a number of the SciDAC teams. ORNL also supports Advanced Computing Research Testbeds (ACRTs) focused on the evaluation of leading edge research computers from Compaq and IBM including significant interactions with SciDAC applications teams. The LTR subprogram at ORNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are high temperature superconducting wires, 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 and participates on a number of the SciDAC teams. The LTR subprogram at PNNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are mathematical simulations of glass production, interactions of biological polymers with model surfaces, and characterization of microorganisms 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 Tonopah, 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 and participates on a number of the SciDAC teams.

Stanford Linear Accelerator Center

The Stanford Linear Accelerator Center (SLAC) is located at the edge of Silicon Valley in California about halfway between San Francisco and San Jose on 426 acres of Stanford University land. The LTR subprogram at SLAC conducts research in areas such as advanced electronics, large-scale ultra-high vacuum systems, radiation physics and monitoring, polarized and high-brightness electron sources, magnet design and measurement, and controls systems through cost-shared collaborations with industry.

Thomas Jefferson National Accelerator Facility

The Thomas Jefferson National Accelerator Facility (TJNAF) is a basic research laboratory located on a 200 acre site in Newport News, Virginia. The LTR subprogram at the TJNAF conducts research in such areas as accelerator and detector engineering, superconducting radiofrequency technology, speed data acquisition, and liquid helium cryogenics through cost-shared collaborations with industry.

All Other Sites

The ASCR program funds research at 71 colleges/universities located in 24 states supporting approximately 117 principal investigators. Also included are funds for research awaiting distribution pending completion of peer review results.

A number of Integrated Software Infrastructure Centers will be established at laboratories and/or universities. Specific site locations will be determined as a result of competitive selection. These centers will focus on specific software challenges confronting users of terascale computers.

Mathematical, Information, and Computational Sciences

Mission Supporting Goals and Objectives

The Mathematical, Information, and Computational Sciences (MICS) subprogram is responsible for carrying out the primary mission of the ASCR program: discovering, developing, and deploying advanced scientific computing and communications tools and operating the high performance computing and network facilities that researchers need to analyze, model, simulate, and — most importantly — predict the behavior of complex natural and engineered systems of importance to the Office of Science and to the Department of Energy.

- A key feature of the ASCR program is that the approach to accomplishing the Program Strategic Performance Goals is integrated through the management of the MICS subprogram. Computing and networking requirements of the Office of Science far exceed the current state-of-the-art; and the requirements far exceed the tools that the commercial marketplace will deliver. The MICS subprogram must not only support basic research in the areas listed above, but also the development of the results from this basic research into software usable by scientists in other disciplines and partnerships with users to test the usefulness of the research. These partnerships with the scientific disciplines are critical because they provide rigorous tests of the usefulness of current advanced computing research, enable MICS to transfer the results of this research to scientists in the disciplines, and help define promising areas for future research. This integrated approach is critical for MICS to succeed in providing the extraordinary computational and communications tools that DOE's civilian programs need to carry out their missions. It is important to note that these tools have applications beyond the Office of Science; to the NNSA and the private sector after these tools have been initially discovered and developed by the MICS subprogram.

In addition to its research activities, the MICS subprogram supports the operation of supercomputer and network facilities that are available to researchers working on problems relevant to DOE's scientific missions 24 hours a day, 365 days a year.

In FY 2003, the MICS subprogram will continue its components of the collaborative SciDAC program across the Office of Science to produce the scientific computing, networking and collaboration tools that DOE researchers will require to address the scientific challenges of the next decade. The MICS components include investments in scientific computing research and networking and collaboration research that are complemented by investments in computing and networking facilities. In addition, in FY 2003, MICS will increase its efforts in computational biology and in computational nanoscience.

The specific details of the MICS investment strategy are described below in the detailed program justification section of this budget. However, it is important to understand that all of those individual program elements are pieces in a puzzle whose overall goal is to enable scientists to use computing and collaboration technologies as tools for scientific discovery. Thus, the way the individual elements fit together and complement each other is critical because a scientist needs all of these pieces to succeed. A weakness in any one element, or weakness in the way the elements are integrated, are barriers to the scientist's success. The three sections below provide the background for MICS subprogram investments in Scientific Computing Research, High Performance Networking, Middleware and Collaboratory Research, and High Performance Computing and Networking Facilities.

Scientific Computing Research Investments

In scientific computing, the key measure of success in translating peak computing power into science is the percent of peak performance that is delivered to an application over the *entire* calculation. In the early to mid-1990's on computers such as the Cray Research C-90, many scientific codes realized 40% to 50% of the peak performance of the supercomputer. In contrast, on today's parallel supercomputers, scientific computing codes often realize only 5% to 10% of "peak" performance, and this fraction could decrease as the number of processors in the computers grow.

This phenomenon is a direct result of the fact that the speed of memory systems and the speed of interconnects between processors is increasing much more slowly than processor speed. For many scientific applications these factors dominate the performance of the application. Two types of solutions are available to the computer hardware designer in addressing the mismatch of speed between the components: (1) clever hierarchical arrangements of memory with varying speeds and software to find data before it is needed and move it into faster memory, closer to the processor that will need it; and (2) techniques to increase parallelism, for example, by using threads in the processor workloads or by combining parallel data streams from memory or disks. Current technology forecasts indicate a doubling or quadrupling in the numbers of layers in the memory hierarchy, and a 100- to 1000-fold increase in the amount of parallelism in disk and tape systems to accommodate the relative increase in the mismatch between processor speed and memory, disk and tape speeds in the next five years.

One result of this increasing complexity of high-performance computer systems is the importance of the underlying systems software. Operating systems, compilers, runtime environments, mathematical libraries, and end-user applications must all work together efficiently to extract the desired high performance from these systems.

In addition to the challenges inherent to managing the required level of parallelism, technology trends and business forces in the U.S. computer system industry have resulted in radically reduced development and production of high-end systems necessary for meeting the most demanding requirements of scientific research. In essence, the U.S. computer industry has become focused on the computer hardware and software needs of business applications, and little attention is paid to the special computational needs of the scientific community. Therefore, to achieve the performance levels required for agency missions and world leadership in computational science, large numbers of smaller commercial systems must be combined and integrated to produce terascale computers. Unfortunately, the operating systems software and tools required for effective use of these large systems are significantly different from the technology offered for the individual smaller components. Therefore, new enabling software must be developed if scientists are to take advantage of these new computers in the next five years.

The following are specific examples of *computer science* research challenges:

- Efficient, high-performance operating systems, compilers, and communications libraries for high-end computers.
- Software to enable scientists to store, manage, analyze, visualize, and extract scientific understanding from the enormous (terabyte to petabyte) data archives that these computers will generate.

- Software frameworks that enable scientists to reuse most of their intellectual investment when moving from one computer to another and make use of lower-level components, such as runtime services and mathematical libraries, that have been optimized for the particular architecture.
- Scalable resource management and scheduling software for computers with thousands of processors.
- Performance monitoring tools to enable scientists to understand how to achieve high performance with their codes.

In addition to these computer science challenges, significant enhancements to the MICS applied mathematical research activity are required for the Department to satisfy its mission requirements for computational science. Over the history of computing, improvements in algorithms have yielded at least as much increase in performance as has hardware speedup. Large proportions of these advances are the products of the MICS applied mathematics research activity. In addition to improving the speed of the calculations, many of these advances have dramatically increased the amount of scientific understanding produced by each computer operation. For example, a class of mathematical algorithms called "fast multipole algorithms," was discovered for a number of important mathematical operations required to process 1,000 datapoints by a factor of 1,000; 10,000 datapoints by a factor of 10,000; and so on. Another example of how powerful these methods can be is that they enable a scientist to process 10,000 datapoints in the time that it would have taken to process 100 using earlier techniques, or 1,000,000 datapoints in the time older techniques would have needed to process 1,000. The requirements of scientific domains for new algorithms that can scale to work effectively across thousands of processors and produce the most science in the fewest number of computer operations drives the need for improved mathematical algorithms and the supporting software libraries that must be made available for ready use by domain scientists. In this area of research the MICS applied mathematics activity is the core of the nationwide effort.

The MICS subprogram will address these challenges by continuing the competitively selected partnerships (based on solicitation notices to DOE national laboratories and universities) focused on discovering, developing, and deploying to scientists key enabling technologies that were initiated in FY 2001. These partnerships, which are called Integrated Software Infrastructure Centers, must support the full range of activities from basic research through deployment and training because the commercial market for software to support terascale scientific computers is too small to be interesting to commercial software providers. These centers play a critical role in providing the software infrastructure that will be used by the SciDAC applications research teams. The management of these centers will build on the successful experience of the MICS subprogram in managing other community software research efforts as a part of its High Performance Computing and Communications program, as well as on the lessons learned in important programs supported by Defense Advanced Research Projects Agency (DARPA) such as Project Athena at MIT, the Berkeley UNIX Project, and the initial development of the Internet software and the Internet Activities Board (IAB). These Integrated Software Infrastructure Centers will have close ties to key scientific applications projects to ensure their success.

The efforts initiated in FY 2001 address the important issues of understanding and developing the tools that applications developers need to make effective use of machines that will be available in the next several years.

The MICS activities that respond to these challenges are described later in the Detailed Program Justification section of the MICS subprogram budget under the headings:

- Applied Mathematics,
- Computer Science, and
- Advanced Computing Software Tools.

High Performance Networking, Middleware and Collaboratory Research Investments

Advances in network capabilities and network-enabled technologies now make it possible for large geographically distributed teams to effectively collaborate on the solution of complex problems. It is now becoming possible to effectively harness and integrate the collective capabilities of large geographically distributed computational facilities, data archives, and research teams. This new capability is especially important for the teams using the major experimental facilities, computational resources, and data resources supported by DOE because all of the necessary resources are not available at one location.

- Significant research is needed to augment the capability and performance of today's networks, including the Internet, in order to develop high-performance network infrastructures that support distributed high-end data-intensive applications and secure large-scale scientific collaboration. The requirements of high-performance networks that support distributed data-intensive computing and scientific collaborations on a national and international scale are very different than the requirements of the current commercial networks where millions of users are moving small web pages. The MICS-supported research on high-performance networks includes research on high-performance protocols, network-aware operating system services, advanced network coprocessors, network measurement and analysis, and traffic models of large single flows.
- Research is also needed for the development and testing of high-performance middleware needed to seamlessly couple scientific applications to the underlying transport networks. These include high-performance middleware such as advanced security services for grid computing, ultra-high-speed data transfer services, services to guarantee Quality of Service (QoS) for delay sensitive applications, and grid resources discovery. These high-performance middleware provide the scalable software components needed to integrated distributed data archives, high performance disk caches, visualization and data analysis servers, authentication and security services, computational resources, and the underlying high-speed network networks into a scalable and secure scientific collaborative environment.

The MICS subprogram will address these challenges through an integrated program of fundamental research in networking and collaboratory tools, partnerships with key scientific disciplines, and advanced network testbeds.

Specific responses to these challenges are described in the Detailed Program Justification section of the MICS subprogram budget under the headings:

- Networking,
- Collaboratory Tools, and
- National Collaboratory Pilot Projects.

Enhancements to High Performance Computing and Networking Facilities

To realize the scientific opportunities offered by advanced computing, enhancements to the Office of Science's computing and networking facilities are also required. The MICS subprogram supports a suite of high-end computing resources and networking resources for the Office of Science:

- **Production High Performance Computing Facilities.** The National Energy Research Scientific Computing Center (NERSC) provides high performance computing for investigators supported by the Office of Science. NERSC provides a spectrum of supercomputers offering a range of high performance computing resources and associated software support.
- **Energy Sciences Network (ESnet).** ESnet provides worldwide access to Office of Science facilities, including light sources, neutron sources, particle accelerators, fusion reactors, spectrometers, high-end computing facilities and other leading-edge instruments and facilities.
- **Advanced Computing Research Testbeds.** These testbeds provide advanced computational hardware for testing and evaluating new computing hardware and software. These testbeds are providing specialized computational resources to support SciDAC applications teams in FY 2002. In FY 2003, this activity will be enhanced to provide specialized computing resources to SciDAC application teams.

Current production supercomputing resources provided less than half of the resources that were requested last year. The pressure on production facilities will only increase in future years as more applications become ready to move from testing the software to using the software to generate new science. In addition, as the speed of computers increases, the amount of data they produce also increases. Therefore, focused enhancements to the Office of Science's network infrastructure are required to enable scientists to access and understand the data generated by their software. These network enhancements are also required to allow researchers to have effective remote access to the experimental facilities that the Office of Science provides for the Nation.

The MICS subprogram activities that respond to these challenges are described later in the Detailed Program Justification section of the MICS subprogram budget under the headings:

- National Energy Research Scientific Computing Center (NERSC),
- Advanced Computing Research Testbeds, and
- Energy Sciences Network (ESnet).

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Mathematical, Computational, and Computer Sciences Research	57,434	70,315	78,620	+8,305	+11.8%
Advanced Computation, Communications Research and Associated Activities	94,213	80,139	83,782	+3,643	+4.5%
SBIR/STTR	0	3,946	4,223	+277	+7.0%
Total, Mathematical, Information, and Computational Sciences	151,647	154,400	166,625	+12,225	+7.9%

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
Mathematical, Computational, and Computer Sciences Research	**57,434**	**70,315**	**78,620**
■ **Applied Mathematics**	**27,110**	**32,000**	**24,634**

Research is conducted on the underlying mathematical understanding and numerical algorithms to enable effective description and prediction of physical systems. Research in applied mathematics is critical to the DOE's mission because improved mathematical techniques enable large computational simulations. As discussed earlier in the MICS subprogram overview, improvements in mathematical algorithms are responsible for greater improvement in scientific computing capabilities than the increases in hardware performance. This activity supports research at DOE laboratories, universities, and private companies at a level similar to previous years. Many of the projects supported by this activity are partnerships among researchers at universities and DOE laboratories. The program supports research in a number of areas including: ordinary and partial differential equations, including numerical linear algebra, iterative methods and preconditioners, sparse solvers, and dense solvers; fluid dynamics, including compressible, incompressible and reacting flows, turbulence modeling, and multiphase flows; optimization, including linear and nonlinear programming, interior-point methods, and discrete and integer programming; mathematical physics; control theory, including differential-algebraic systems, order reduction, queuing theory; shock wave theory systems, multipole expansions, mixed elliptic-hyperbolic problems, including hyperbolic and wavelet transforms; dynamical systems, including chaos-theory and control, and bifurcation theory; programming; and geometric and symbolic computing, including minimal surfaces and automated reasoning systems.

The FY 2003 budget continues the FY 2001 increased level of funding for the Computational Sciences Graduate Fellowship program. In addition, the FY 2003 budget includes a $2,000,000 increase to support basic research in applied mathematics focused on developing the mathematical understanding and techniques needed for our partnership with the Biological and Environmental

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

Research program. This partnership focuses on understanding microbes that address DOE energy and environmental needs through a research program on the leading edge of biology. The research will offer new ways to solve environmental challenges related to DOE's missions, including toxic waste cleanup, new clean energy sources and global climate stabilization through carbon sequestration. New research in applied mathematics is needed to support this partnership because the needs of biologists include areas of mathematical research such as graph theory, combinatorics, control theory, and advanced statistics research that are not supported by the existing program.

FY 2003 funding for the competitively selected Integrated Software Infrastructure Centers (ISICs) partnerships focused on algorithms and mathematical libraries for critical DOE applications on terascale computers, which had previously been under this activity, has been transferred to the Advanced Computing Software Tools activity, along with the FY 2003 funding for the ISICs that had previously been under the Computer Science activity. This transfer enables a clearer discussion of these activities and a clearer relationship to the ASCR Program Strategic Performance Goals.

Performance will be measured in a number of ways. Efforts in applied mathematics will be evaluated on an ongoing basis for their leadership and significant contributions to the worldwide applied mathematics effort using measures including a number of awards, significant advances, and invited participation and membership on organizing and program committees of major national and international conferences (SC5-1; SC5-2). The Computational Science Graduate Fellowship Program will appoint 20 new students to develop the next generation of leaders in computational science for DOE and the Nation (SC5-1).

	FY 2001	FY 2002	FY 2003
■ **Computer Science**..	**20,941**	**21,051**	**19,000**

Research in computer science to enable large scientific applications is critical to DOE because its unique requirements for high performance computing significantly exceed the capabilities of computer vendors' standard products. Therefore, much of the computer science to support this scale of computation must be developed by DOE. This activity supports research in two general areas: the underlying software to enable applications to make effective use of computers with hundreds or thousands of processors as well as computers that are located at different sites; and large scale data management and visualization under circumstances where the underlying resources and users are geographically distributed. The first area includes research in protocols and tools for interprocessor communication and parallel input/output (I/O) as well as tools to monitor the performance of scientific applications and advanced techniques for visualizing very large-scale scientific data. Researchers at DOE laboratories and universities, often working together in partnerships, carry out this research.

FY 2003 funding for the competitively selected Integrated Software Infrastructure Centers (ISICs) partnerships focused on computer science research for critical DOE applications on terascale computers, which had previously been under this activity, has been transferred to the Advanced Computing Software Tools activity, along with the FY 2003 funding for the ISICs that had previously been under the Applied Mathematics activity. This transfer enables a clearer discussion of these activities and a clearer relationship to the ASCR Program Strategic Performance Goals.

Performance in computer science will be measured through peer review and regularly scheduled external expert reviews of ongoing projects, production of significant research results, and the adaptation of results and knowledge by other researchers supported by the Office of Science (SC5-1; SC5-2).

	FY 2001	FY 2002	FY 2003
■ **Advanced Computing Software Tools**	**4,421**	**8,473**	**20,256**

This research uses the results of fundamental research in applied mathematics and computer science to develop an integrated set of software tools that scientists in various disciplines can use to develop high performance applications (such as simulating the behavior of materials). These tools, that provide improved performance on high-end systems, are critical to the ability of scientists to attack the complex scientific and engineering problems that can only be solved with high-end computing systems.

In FY 2003, support for all the competitively selected Integrated Software Infrastructure Centers, competitively selected in FY 2001 under SciDAC, to address critical computer science and systems software issues for terascale computers is described in this activity for clarity. FY 2003 funding for basic research in computer science focused on problem solving environments for scientific computing, portable runtime systems, and other basic research in software components, which was previously included in this activity has been transferred to the computer science activity in order to more clearly characterize the research.

The ISICs funded under this activity focus on: structured and unstructured mesh generation for large simulations and high performance tools for solving partial differential equations on parallel computers; tools for analyzing the performance of scientific simulation software that uses thousands of processors; the development of data management and visualization software capable of handling terabyte scale data sets extracted from petabyte scale data archives, and software for managing computers with thousands of processors; and software component technology to enable rapid development of efficient, portable, high performance parallel simulation software.

These Integrated Software Infrastructure Centers are a critical component in DOE's strategy for SciDAC. The ISICs differ from the other activities in this program element because they are responsible for the entire lifecycle of the software that they develop. From the experience gained with end user application scientists applying previous software tools, it has become clear that to promote wide usage across the scientific community, the tools must also be reliable, documented, and easy to use. In addition, users of the tools need the tools to be maintained so that the tools continue to be available, have bugs fixed, etc. Since many of the tools needed in the high performance arena have no commercial market, the Integrated Software Infrastructure Centers initiated in FY 2001 will provide a means for focused investment to deploy these tools to the scientific community.

	(dollars in thousands)	
FY 2001	FY 2002	FY 2003

Performance will be measured through peer review and regularly scheduled external expert reviews of ongoing projects, production of significant research results, and the adaptation of results and knowledge by other researchers in the Office of Science (SC5-1; SC5-2). In addition, these ISICs will undergo a progress review to ensure effective coupling between the ISICs and between the ISICs and application teams in the MICS Scientific Applications Pilot Projects efforts and in the SciDAC teams funded by the other programs in the Office of Science (SC5-2).

	FY 2001	FY 2002	FY 2003
■ **Scientific Applications Pilot Projects**..................................	**4,962**	**8,791**	**14,730**

This research is a collaborative effort with disciplinary computational scientists to apply the computational techniques and tools developed by MICS supported research to basic research problems relevant to the mission of SC. This effort tests the usefulness of current advanced computing research, transfers the results of this research to the scientific disciplines, and helps define promising areas for future research. The FY 2003 funding for this activity will allow the continuation of the pilot projects that were competitively selected in FY 2001. These pilot projects are tightly coupled to the Integrated Software Infrastructure Centers (described above in advanced computing software tools) to ensure that these activities are an integrated approach to the challenges of terascale simulation and modeling that DOE faces to accomplish its missions. These partnerships include areas such as design of particle accelerators with the High Energy and Nuclear Physics (HENP) program; plasma turbulence in tokamaks with the Fusion Energy Sciences (FES) program; global climate change with the Biological and Environmental Research (BER) program; and combustion chemistry with the Basic Energy Sciences (BES) program. The increase in funding in this program activity will focus on expanding our partnership with BER and establishing a new partnership with BES. This expansion of the partnership with BER includes an increase of approximately $3,000,000 in FY 2003, which further develops the computational research infrastructure needed to study microbial communities that may have applications to clean energy, environmental cleanup, and carbon sequestration and especially underlying mathematical understanding and computational tools that are needed for the analysis and simulation of these biological processes. The new partnership with the BES program includes approximately $3,000,000 for computational nanoscale science engineering and technology. This partnership is an integral part of the Nanoscale Science, Engineering and Technology initiative in the Office of Science, that is led by the BES program. These new research teams will focus on using high performance computers to answer fundamental questions such as the emergence of collective phenomena -- phenomena that emerge from the interactions of the components of the material and whose behavior thus differs significantly from the behavior of those individual components. In some cases, collective phenomena can bring about a large response to a small stimulus -- as seen with colossal magnetoresistance, the basis of a new generation of recording memory material. Collective phenomena are also at the core of the mysteries of such materials as the high-temperature superconductors, one of the great outstanding problems in condensed matter physics. All of these new projects will be selected through open, peer reviewed competitive processes.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

Performance will be measured through peer review, external expert reviews of ongoing projects, production of significant research results, and the adaptation of results and knowledge by other researchers supported by the Office of Science (SC5-2).

	FY 2001	FY 2002	FY 2003
Advanced Computation, Communications Research, and Associated Activities	**94,213**	**80,139**	**83,782**
■ **Networking**	**7,507**	**7,066**	**7,066**

Research is needed to develop high-performance networks that are capable of supporting distributed high-end computing and secure large-scale scientific collaboration. High performance networks enable scientists to collaborate effectively and to have efficient access to distributed computing resources such as tera-scale computers, experimental scientific instruments, and large scientific data archives. This research is carried out at national laboratories and universities. It focuses in areas such as high-performance transport protocols for high-speed networks; scalable techniques for measuring, analyzing, and controlling traffic in high performance networks; network security research to support large-scale scientific collaboration; advanced network components to enable high-speed connections between terascale computers, large scientific data archives, and high-speed networks; and research on high-performance "middleware." Middleware is a collection of network-aware software components that scientific applications need in order to couple efficiently to advanced network services and make effective use of experimental devices, data archives, and terascale computers at different locations. In all of these cases, the network and middleware requirements of DOE significantly exceed those of the commercial market.

Performance will be measured through peer review, external expert reviews of ongoing projects, production of significant research results, and the adaptation of results and knowledge by other researchers supported by the Office of Science and other Federal Agencies (SC5-1; SC5-2).

	FY 2001	FY 2002	FY 2003
■ **Collaboratory Tools**	**5,915**	**5,527**	**5,527**

This research uses the results of fundamental research in computer science and networking to develop an integrated set of software tools to support scientific collaborations. This includes enabling scientists to remotely access and control facilities and share data in real time, and to effectively share data with colleagues throughout the life of a project. These tools provide a new way of organizing and performing scientific work that offers the potential for increased productivity and efficiency and will also enable broader access to important DOE facilities and data resources by scientists and educators across the country. It is particularly important to provide for efficient, high-performance, reliable, secure, and policy-aware management of large-scale data movement. This research includes an effort to develop a set of essential middleware services required to support large-scale data-intensive collaboratory applications. This research also includes an effort to research, develop, and integrate the tools required to support a flexible, secure, seamless collaboration environment that supports the entire continuum of interactions between collaborators. The goal is to seamlessly allow collaborators to locate each other, use asynchronous and synchronous messaging, share documents, progress, results, applications and

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

hold videoconferences. There is also research for developing and demonstrating an open, scalable approach to application-level security in widely distributed, open network environments that can be used by all the collaboratory tools as well as by the advanced computing software tools whenever access control and authentication are issues. Finally, another example of research in collaboratory tools is the development of a scientific annotation middleware system that will provide significant advances in research documentation and data pedigree tracking. Researchers access the system through a notebook interface as well as through components embedded in other software systems. It will provide more complete, effective and efficient ways to document scientific work.

Performance will be measured through peer review, and regularly scheduled external expert reviews of ongoing projects, production of significant research results, and the adaptation of results by other researchers supported by the Office of Science and other Federal Agencies (SC5-2).

	FY 2001	FY 2002	FY 2003
■ **National Collaboratory Pilot Projects**	**8,245**	**10,857**	**10,857**

This program is intended to test, validate, and apply collaboratory tools in real-world situations in partnership with other DOE programs. The competitively selected partnerships involve national laboratories, universities, and U.S. industry. It is important to continue to demonstrate and test the benefits of collaboratory tools technology in order to promote its widespread use and enable more effective access to the wide range of resources within the Department, from light sources to terascale computers to petabyte data storage systems. The partnerships that were initiated in FY 2001 focus on developing user environments where collaboration is ubiquitous and distributed computing is seamless and transparent for DOE mission applications. The Particle Physics Data Grid is developing middleware infrastructure to support High Energy Physics and Nuclear Physics (HENP) communities, and to enable grid-enabled data-management ("manipulation") and analysis capabilities "at the desk of every physicist." It is building one unified system that will be capable of handling the capture, storage, retrieval and analysis of particle physics experiments at the five most critical research facilities, a key collaboratory issue being the highly distributed access to, and processing of, the resulting data by a worldwide research community. In another community, the Earth System Grid II developing a virtual collaborative environment linking distributed centers, models, data, and users that will facilitate exchange among climatologists all over the world and provide a badly needed platform for the management of the massive amounts of data that are being generated. Development of this and similar concepts is essential for rapid, precise, and convincing analysis of short- and long-term weather patterns, particularly in the period when increasing pollution introduces changes that may affect us for generations to come. The National Fusion Collaboratory is centered on the integration of collaborative technologies appropriate for widely dispersed experimental environments and includes elements of security, distributed systems, and visualization. All three of these pilot collaboratories will rely on the DOE Science Grid to provide the underpinnings for the software environment, the persistent grid services, that make it possible to pursue innovative approaches to scientific computing through secure remote access to online facilities, distance collaboration, shared petabyte datasets and large-scale

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

distributed computation. This level of funding will permit the continuation of the efforts funded in FY 2001.

Performance will be measured through peer review, and regularly scheduled external expert reviews of ongoing projects, production of significant research results, and the adaptation of results by other researchers supported by the Office of Science (SC5-2).

■ **National Energy Research Scientific Computing Center (NERSC)**	**34,361**	**28,244**	**28,244**

NERSC, located at LBNL, provides high performance computing for investigators supported by the Office of Science. The Center serves 2,400 users working on about 700 projects; 36 percent of users are university based, 59 percent are in National Laboratories, 4 percent are in industry, and 1 percent in other government laboratories. NERSC provides a spectrum of supercomputers offering a range of high performance computing resources and associated software support. The two major computational resources at NERSC are a 512 processor Cray T3E computer and a 2,944 processor IBM SP computer whose installation was completed in late FY 2001 following a fully competitive procurement process. The FY 2003 funding will support the operation of the IBM-SP computer at about 5.0 teraflops "peak" performance. These computational resources will be integrated by a common high performance file storage system that facilitates interdisciplinary collaborations. Related requirements for capital equipment, such as high-speed disk storage systems, archival data storage systems, and high performance visualization hardware, and general plant projects (GPP) funding are also supported. FY 2003 capital equipment requirements continue at the same level as in FY 2002. The competitive process for upgrading hardware (NERSC-4) is underway. The target date for the installation of NERSC-4 Phase I hardware is mid FY 2003. Expected performance will be greater than 10 teraflops.

Performance will be measured in a number of ways. Hardware performance is determined by computing the percentage of time the machine is actually available to users, which excludes scheduled downtime for maintenance, etc. This will be 90 percent or more of the total scheduled operating time. In FY 2001, the measured operating time lost to unscheduled downtime on systems at NERSC ranged from 0 percent to 1.34 percent. Overall performance of the center is measured by user surveys that will continue to show a high degree of satisfaction with the services at NERSC and annual reports that will continue to demonstrate production of world-class science being done at the facility. NERSC will be operated within budget while meeting user needs and satisfying overall SC program requirements (SC5-2; SC7-5)

■ **Advanced Computing Research Testbeds (ACRTs)**...........	**20,057**	**11,657**	**15,300**

This activity supports the advanced computational hardware testbeds that play a critical role in testing and evaluating new computing hardware and software, especially with regard to their applicability to scientific problems. Current testbeds are located at Argonne National Laboratory (IBM/ Intel Cluster); and ORNL (Compaq-Alpha technology and IBM Power –4 technology). These testbeds represent the evolution of Advanced Computing Research Facilities that supported the computational requirements of the scientific application partnerships that were completed in

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

FY 2000. Support for the Nirvana Blue Computer Testbed at LANL was phased out in FY 2001. This activity also supports the distributed high performance storage system (HPSS) testbed collaboration between ORNL and LBNL. 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 testbeds must procure the largest scale systems that can be afforded and develop software to manage and make them useful. In addition, the ACRTs, taken together, must have a full range of computer architectures to enable comparison and reduce overall program risk. These all involve significant research efforts, often in partnership with the vendors to resolve issues including operating system stability and performance, system manageability and scheduling, fault tolerance and recovery, and details of the interprocessor communications network. Therefore, these systems are managed as research programs and not as information technology investments. The additional funding in this program element will enhance the ability of these testbeds to provide specialized computational resources to support SciDAC applications teams in FY 2003.

Performance will be measured by the importance of the research that results from these testbeds as viewed by publications in the scientific literature, the ASCR Advisory Committee and external reviews and the demand for access to these facilities by the nationwide computer and computational science communities (SC5-2; SC7-5)

	FY 2001	FY 2002	FY 2003
■ **Energy Sciences Network (ESnet)**	**18,128**	**16,788**	**16,788**

ESnet is a high-performance network infrastructure that supplies the DOE science community with capabilities not available on current commercial networks or the commercial Internet. It provides national and international high-speed access to the DOE and to the Office of Science research facilities, including: advanced light sources; neutron sources; particle accelerators; fusion reactors; spectrometers; supercomputers; Advanced Computing Research Testbeds (ACRTs); and other leading-edge science instruments and facilities. ESnet provides the communications fabric that interconnects geographically distributed research facilities and large-scale scientific collaboration. It supplies the critical infrastructure that links DOE researchers worldwide and forms the basis for advanced experimental research in networking, collaboratory tools, and distributed data-intensive scientific applications testbeds such as the national collaboratory pilot projects. For day-to-day operation, DOE employs ESnet management at LBNL, who contracts with commercial vendors for advanced communications services including Asynchronous Transfer Mode (ATM), Synchronous Optical Networks (SONET) and Dense Wave Division Multiplexing (DWDM). In addition, LBNL ESnet management is responsible for the interfaces between the network fabric it provides and peering arrangements with other Federal, education and commercial networks, international research network connections, and the University Corporation for Advanced Internet Development (UCAID) Abilene network that provides high performance connections to many research universities. The FY 2003 funding will support the continued operation of ESnet and will meet capital equipment needs to upgrade high-speed network routers, ATM switches, and network testing equipment.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

Performance will be measured in several ways. The operating time lost due to unscheduled ESnet downtime in FY 2003 will be less than 10 percent of the total scheduled possible operating time. In FY 2001, the measured operating time lost to unscheduled downtime on ESnet was 3 percent of total scheduled operating time. In FY 2003, ESnet will operate within budget while meeting user needs and satisfying overall SC program requirements. Network enhancements will improve researchers access to high performance computing and software support, and enhance scientific opportunities by enabling scientists to access and understand greater amounts of scientific data and benefit DOE and scientific research (SC5-2; SC7-5).

	FY 2001	FY 2002	FY 2003
SBIR/STTR	**0**	**3,946**	**4,223**

In FY 2001, $3,748,000 and $225,000 were transferred to the SBIR and STTR programs, respectively. The FY 2002 and FY 2003 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.

	FY 2001	FY 2002	FY 2003
Total, Mathematical, Information, and Computational Sciences	**151,647**	**154,400**	**166,625**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)

Mathematical, Computational, and Computer Sciences Research

- **Applied Mathematics.** Provides an increase to the Applied Mathematics program element to support research in applied mathematics for biological problems plus a small enhancement to the Computational Science Graduate Fellowship program ($2,366,000). The new research in applied mathematics will focus on the mathematics needed by biologists to understand microbes and include areas of mathematical research such as graph theory, combinatorics, control theory, and advanced statistics research. Funding for the ISICs previously included in the Applied Mathematics program element is transferred to the Advanced Computing Software Tools program element (-$9,732,000). This transfer more clearly identifies the special role of the ISICs and clarifies the budget description. .... -7,366

	FY 2003 vs. FY 2002 ($000)
■ **Computer Science.** Transfers funding for the ISICs previously included in the Computer Science program element to the Advanced Computing Software Tools program element (-$7,051,000). Transfers funding for basic research in computer science focused on problem solving environments for scientific computing, portable runtime systems, and other basic research in software components, which was previously included in the Advanced Computing Software Tools program element to the Computer Science program element ($5,000,000). These transfers more clearly identify the special role of the ISICs and clarify the budget description..........	-2,051
■ **Advanced Computing Software Tools.** Transfers funding for the ISICs previously included in the Applied Mathematics ($9,732,000) and Computer Science ($7,051,000) program elements to the Advanced Computing Software Tools program element. Transfers funding for basic research in computer science focused on problem solving environments for scientific computing, portable runtime systems, and other basic research in software components, which was previously included the Advanced Computing Software Tools program element (-$5,000,000) to the Computer Science program element. These transfers more clearly identify the special role of the ISICs and clarifies the budget description....	+11,783
■ **Scientific Application Pilot Projects.** Provides additional funding to double the number of pilot projects in the partnership with BER on computational biology, and to enable a number of new partnerships with BES focused on computational nanoscience. The new, competitively selected research teams in the partnership with BER will focus on the computational tools that are needed for the analysis and simulation of biological processes such as protein folding and gene regulation. The new, competitively selected research teams in the partnership with BES will focus on using high performance computers to answer fundamental questions in nanoscale science such as the emergence of collective phenomena..........	+5,939
Advanced Computation, Communications Research, and Associated Activities	
■ **Advanced Computing Research Testbed.** Provides an increase in this program element to establish a minimal high-performance computing capability for Topical Applications, providing an architecture tailored to a class of applications within the SciDAC research portfolio to produce new science, including required upgrades to ESnet infrastructure..........	+3,643
SBIR/STTR	
■ Increase in SBIR/STTR due to increase in operating expenses.	+277
Total Funding Change, Mathematical, Information, and Computational Sciences	+12,225

Laboratory Technology Research

Mission Supporting Goals and Objectives

The mission of the Laboratory Technology Research (LTR) subprogram is to support high-risk 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. Therefore, the LTR subprogram is responsible for one of the ASCR Program Strategic Performance Goals:

An important component of the Department's strategic goals are 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 subprogram component provides funding to the Office of Science national laboratories to facilitate rapid access 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 four critical areas of DOE mission-related research: advanced materials processing and utilization, nanotechnology, intelligent processes and controls, and energy-related applications of biotechnology.

Funding Schedule

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Laboratory Technology Research	9,649	2,921	2,921	0	--
SBIR/STTR	0	79	79	0	--
Total, Laboratory Technology Research..	9,649	3,000	3,000	0	--

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Laboratory Technology Research	**9,649**	**2,921**	**2,921**

This activity supports research to advance the fundamental science at the Office of Science (SC) laboratories toward innovative energy applications. Through CRADAs, the SC laboratories enter into cost-shared research partnerships with industry, typically for a period of three years, to explore energy applications of research advances in areas of mission relevance to both parties. The research portfolio consists of 12 projects and emphasizes the following topics: advanced materials processing and utilization, nanotechnology, intelligent processes and controls, and energy-related applications of biotechnology. Efforts underway include the exploration of (1) new cast steels with microstructures and mechanical properties better than comparable cast alloys, to provide an improved critical component material for higher efficiency steam and gas turbine technology for electric power generation; (2) radiative carrier recombination in group-III nitride thin films, to optimize the performance of GaN-based high-brightness Light Emitting Diodes for applications in energy-efficient lighting; and (3) molecular structures of new classes of hydroporphyrin photosensitizers for use with light and oxygen to destroy cancerous cells and tissues. A small but important component of this activity provides industry, particularly small businesses, with rapid access to the unique research capabilities and resources at the SC laboratories. These research efforts are usually supported for a few months to quantify the energy benefit of a specific problem posed by industry. Recent projects supported the development of: (1) an economically-viable duplex chromium nitride near-frictionless carbon film capable of providing extreme wear resistance and reduced friction to sliding engine and drive train components in advanced diesel engines; (2) a detailed understanding of the interplay between platinum/cadmium zinc telluride interfacial chemistry and radiation detector performance for applications such as finding new cancer locations; and (3) an ion source for producing negative heavy ions for ion implantation in the semiconductor industry, which will eliminate toxic gas.

Performance in this activity will be measured through merit-based peer and on-site reviews.

SBIR/STTR	**0**	**79**	**79**

In FY 2001, $242,000 and $14,000 were transferred to the SBIR and STTR programs, respectively. The FY 2002 and FY 2003 amounts are the estimated requirement for the continuation of the SBIR and STTR program.

Total, Laboratory Technology Research	**9,649**	**3,000**	**3,000**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
There are no significant funding changes.	

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
General Plant Projects	0	1,000	1,000	0	--
Capital Equipment (total)	5,213	5,130	6,250	+1,120	+21.8%
Total, Capital Operating Expenses	5,213	6,130	7,250	+1,120	+18.3%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2001	FY 2002	FY 2003	Accept-ance Date
Distributed Visualization Server – LBNL	2,500	0	2,500	0	0	FY 2001
Total, Major Items of Equipment		0	2,500	0	0	

Energy Research Analyses

Program Mission

The mission of the Energy Research Analyses (ERA) program is to provide the capabilities needed to evaluate the scientific excellence, relevance, and international leadership of the Office of Science basic science research programs; to advance the understanding of how the Office of Science contributes to DOE and national mission goals; and to contribute to the effective management of the department's science enterprise.

Strategic Objective

SC-8: Ensure efficient SC program management of research and construction projects through a re-engineering effort by FY 2003 that will support world class science through systematic improvements in SC's laboratory physical infrastructure, security, and ES&H.

Progress toward accomplishing this Strategic Objectives will be measured by a Program Strategic Performance Goal, Indicators and Annual Targets, as follows:

Program Strategic Performance Goals

SC8-1: By FY 2007, develop best in class evaluation tools and methods, science management practices, and communication capabilities that enable Office of Science basic research programs to meet critical DOE and national mission requirements.

Performance Indicators

Number and quality of evaluation techniques adopted by SC.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Launched several research management studies to identify: 1) best practices in benchmarking, 2) best practices to administer public science communication, 3) effective use of quantitative performance measures to evaluate the societal impact of basic research, and 4) a case study methodology to ensure the success of future case studies of societal impact of SC science. (Met goal)	Improve and integrate performance planning and measures between budget documents and DOE performance plans; conduct six pilot retrospective and/or prospective studies to examine the societal impact of SC research. (SC8-1)	Publish results of quantitative performance measures study in open literature; fully incorporate results into SC evaluation regime. Conduct at least six studies/year to demonstrate the societal impact of SC science programs. (SC8-1)

Significant Accomplishments and Program Shifts

- The Office of Science (SC) responsiveness to Government Performance and Results Act (GPRA) requirements was improved in FY 2001 through an evaluation of performance measures, tools and mechanisms and the launching of a research management best practices benchmarking study.
- The Department of Energy Science Portfolio was updated in FY 2001 to better characterize the R&D efforts within the Department with regard to basic research. This portfolio will be maintained to assist the Director of the Office of Science in managing the Department's Science investments.
- Science policy studies and scientific research trend analyses were provided to Office of Science program managers and to other public science organizations in FY 2001, including the first results of a three-year study of international science trends that will inform SC's future strategic planning efforts.
- The FY 2003 program is continuing at the same level as FY 2002, but shifting its emphasis to new methods of evaluation of the science managed by the Office of Science. This shift in emphasis results from research conducted in FY 2001 and continuing in FY 2002 that was designed to create new evaluation tools (e.g., case studies, quantitative measures, and data mining) that will help to validate the excellence, relevance and leadership of the Office of Science programs. In addition, research projects will be sponsored in FY 2003 to demonstrate the societal impact of SC science programs and to create sophisticated data models and analysis techniques to better illustrate scientific trends and achievements.

Funding Profile

(dollars in thousands)

	FY 2001 Comparable Appropriation	FY 2002 Original Appropriation	FY 2002 Adjustments	FY 2002 Comparable Current Appropriation	FY 2003 Request
Energy Research Analyses					
Energy Research Analyses	950	1,000	-5	995	1,020
Subtotal, Energy Research Analyses	950	1,000	-5	995	1,020
General Reduction	0	-5	5	0	0
Total Energy Research Analyses	950[a]	995	0	995	1,020

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

[a] Excludes $25,000 which was transferred to the SBIR and $1,000 which was transferred to the STTR program.

Funding by Site

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Albuquerque Operations Office					
Sandia National Lab/Albuquerque	200	5	100	+95	+1,900.0%
Chicago Operations Office					
Fermi National Accelerator Laboratory	22	0	0	0	--
Chicago Operations Office	200	357	310	-47	-13.2%
Total, Chicago Operations Office	222	357	310	-47	-13.2%
Oak Ridge Operations Office					
Oak Ridge Institute for Science and Education	77	0	55	+55	--
Oakland Operations Office					
Lawrence Berkeley National Laboratory	50	0	50	+50	--
Richland Operations Office					
Pacific Northwest National Laboratory	401	254	465	+211	+83.1%
Washington Headquarters	0	379	40	-339	-89.4%
Total, Energy Research Analyses	950 [a]	995	1,020	+25	+2.5%

[a] Excludes $25,000 which was transferred to the SBIR and $1,000 which was transferred to the STTR program.

Site Description

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. This activity contributes to the Energy Research Analyses program's formulation of long-term and strategic plans.

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 facilitates and coordinates communication and outreach activities, and conducts studies on workforce trends in the sciences.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on a 640 acre site at the Department's Hanford site in Richland, Washington. PNNL carries out research in the areas of portfolio 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, trends in Federal and private sector investments in energy R&D, and science management trends and benchmarking.

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 Tonopah, Nevada. SNL carries out research in the areas of technical program planning and merit review practices to contribute to the Energy Research Analyses program's formulation of best practices for long term plans, science policy and peer reviews. This activity includes assessments of best practices in research and development organizations.

All Other Sites

Includes funds for research awaiting distribution pending finalization of program office detailed planning.

Energy Research Analyses

Mission Supporting Goals and Objectives

The ERA program supports Office of Science programs through the development of management tools and support, analysis of policy direction set by the Administration and the Congress, development and integration of Office of Science strategic plans and research portfolios, evaluation of programs and performance, and facilitation of SC collaborations with other Federal agencies and major stakeholders.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Energy Research Analyses.................	950	969	993	+24	+2.5%
SBIR/STTR	0	26	27	+1	+3.8%
Total, Energy Research Analyses	950	995	1,020	+25	+2.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Energy Research Analyses	**950**	**969**	**993**

In FY 2003, ERA will focus on four major areas:

- *Evaluation studies* will be conducted by independent researchers to identify trends in the DOE research portfolio and potential societal impacts of research, as well as areas of portfolio performance that could be optimized.
- *Research projects* will inform policy direction, characterize key issues in the research environment and their affect on SC programs, and identify potential duplications, gaps and opportunities within the Department's basic research portfolio by collaborating with SC or DOE programs, other agencies, the national laboratories or universities. Research projects are envisioned with universities, laboratories and private sector research performers, and with DOE or SC partners, and entail the conduct of original broad-based research efforts**.**
- *Performance measurement* efforts will develop indicators of SC's international leadership, excellence, and relevance; develop data for a broad suite of quantitative measures used for the Annual Performance Plan and other reports; as well as provide a broad based effort to develop computational tools and visualization techniques designed to manage vast amounts of data to assist in policy and planning forecasting of SC science programs.
- *Stakeholder Collaboration & Communication* will ensure that Office of Science programs are well integrated into the Federal research portfolio and that the societal impact of SC programs is understood.

SBIR/STTR	**0**	**26**	**27**

In FY 2001, $25,000 and $1,000 were transferred to the SBIR and STTR programs, respectively. The FY 2002 and FY 2003 amounts are the estimated requirement for the continuation of the SBIR and STTR program.

Total, Energy Research Analyses	**950**	**995**	**1,020**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Energy Research Analyses	
■ The FY 2003 program is continuing at the same level, but is shifting emphasis to communications and research activities to support science managed and funded by the Office of Science programs.	+24
SBIR/STTR	
■ Increase in SBIR/STTR due to increase in operating expenses.	+1
Total Funding Change, Energy Research Analyses	+25

Science Laboratories Infrastructure

Program Mission

The mission of the Science Laboratories Infrastructure (SLI) program (formerly the Multiprogram Energy Laboratories – Facilities Support program) is to conduct Departmental research missions at the Office of Science (SC) multiprogram and program dedicated laboratories by funding: line item construction to maintain the general purpose infrastructure (GPI); and the clean-up and removal of excess facilities. The program also supports SC landlord responsibilities for the 36,000 acre Oak Ridge Reservation and provides Payments in Lieu of Taxes (PILT) to local communities around ANL-E, BNL, and ORNL.

Strategic Objective

SC8-2: Ensure efficient SC program management of research and construction projects through a re-engineering effort of SC processes by FY 2003 that will support world-class science through systematic improvements in SC's laboratory physical infrastructure, security, and ES&H.

Progress toward accomplishing this Strategic Objective will be measured by Program Strategic Performance Goals, Indicators and Annual Targets, as follows:

Program Strategic Performance Goals

SC8-2A: Reduce the Recapitalization Period (RP) from 170 years in FY 2002 to 80 in FY 2005. The RP is defined as the number of years it takes to replace/rehabilitate the existing general purpose infrastructure (GPI) at a given capital investment level. This period is computed by dividing the replacement plant value of the GPI by the annual capital investment funding level (composed of general plant projects (GPP) funding, general purpose equipment (GPE) funding and general purpose line item (LI) funding. (Laboratories Facilities Support subprogram)

Performance Indicator

The reduction in the RP from year to year

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Based on capital investment funding level of $73,000,000 in FY 2001, the RP is 163 years. (Met goal.)	Based on capital investment funding level of $70,000,000 for FY 2002, the RP will be 170 years. (SC8-2A)	Based on proposed capital investment funding level of $83,000,000 for FY 2003, the RP will decline to 143 years. (SC8-2A)

SC8-2B: Eliminate all excess SC facilities by the end of FY 2008. The backlog of excess facilities projects that can be eliminated in the next few years is currently estimated at 29. This figure does not include 29 "contaminated" excess facilities identified as candidates for transfer to the Office of Environmental Management in FY 2003 and FY 2004. (Excess Facilities Disposition subprogram)

Performance Indicator

Reductions as measured by the number (and percentage) of excess facilities and square footage (and percent of total excess space) removed (or made usable).

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
N/A – no program	A Congressionally added FY 2002 Facilities and Infrastructure (F&I) Program of $10,000,000 will allow the clean-up/removal of approximately 30 excess facilities with a reduction of approximately 400,000 square feet in FY 2002. (SC8-2B)	Estimated disposal (or cleanout) of 10 (34% of 29 total) facilities with a reduction of approximately 176,000 square feet (35% of total). (SC8-2B)

Significant Accomplishments and Program Shifts

- Broaden program to include all SC program dedicated laboratories along with the multiprogram laboratories. These program dedicated laboratories include Ames Laboratory, Fermi National Accelerator Laboratory, Oak Ridge Institute for Science and Education, Princeton Plasma Physics Laboratory, Thomas Jefferson National Accelerator Facility, and Stanford Linear Accelerator Center.
- Include in the Science Laboratories Infrastructure program an Excess Facilities Disposition subprogram to address the disposition of excess facilities resulting in economies and efficiencies in laboratory operations.
- Progress in Line Item Projects – Three projects were completed in FY 2001: the ANL-E Central Supply Facility; the BNL Electrical Systems Modifications, Phase I; and the ANL-E Electrical Systems Upgrade, Phase III. Two projects are scheduled for completion in FY 2002: LBNL Building 77 - Rehabilitation of Building Structure and Systems, Phase I and the BNL Sanitary Systems Modifications, Phase III. Two projects are scheduled for completion in FY 2003: ORNL Electrical Systems Upgrades and the ANL-E Fire Safety Improvements, Phase IV.

Funding Profile

(dollars in thousands)

	FY 2001 Comparable Appropriation	FY 2002 Original Appropriation	FY 2002 Adjustments	FY 2002 Comparable Current Appropriation	FY 2003 Request
Science Laboratories Infrastructure (SLI)					
Laboratories Facilities Support	22,775	22,816	-125	22,691	32,601
Oak Ridge Landlord..........................	4,112	7,359	-2,880	4,479	5,079
Excess Facilities Disposition	0	0	9,960	9,960	5,055
Subtotal, Science Laboratories Infrastructure	26,887	30,175	6,955	37,130	42,735
Facilities and Infrastructure..............	0	10,000[a]	-10,000	0	0
Subtotal Science Laboratories Infrastructure...	26,887	40,175	-3,045	37,130	42,735
General Reduction	---	-165[b]	165	0	0
Total, Science Laboratories Infrastructure	26,887[cd]	40,010	-2,880	37,130	42,735

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

[a] FY 2002 Appropriation provided $10,000,000 in a new program added by Congress titled "Facilities and Infrastructure." Funding for this activity is proposed for inclusion in the Science Laboratories Infrastructure program (Excess Facilities Disposition) in FY 2003.
[b] General reduction includes $125,000 for Science Laboratories Infrastructure (formerly Multiprogram Energy Laboratories – Facilities Support program) and $40,000 for Facilities and Infrastructure.
[c] Excludes $3,047,000 in FY 2001 and $2,880,000 in FY 2002 for Oak Ridge Landlord activities transferred to Science Program Direction in FY 2003.
[d] Excludes $240,000, which was transferred to the Science Safeguards and Security program in an FY 2001 reprogramming.

Funding by Site

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Chicago Operations Office					
Argonne National Laboratory	6,611	3,643	4,205	+562	+15.4%
Brookhaven National Laboratory	6,444	7,413	8,513	+1,100	+14.8%
Princeton Plasma Physics Laboratory	0	875	545	-330	-37.7%
Chicago Operations Office	980	895	1,020	+125	+14.0%
Total, Chicago Operations Office	14,035	12,826	14,283	+1,457	+11.4%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	2,113	6,900	5,607	-1,293	-18.7%
Lawrence Livermore National Laboratory	0	350	250	-100	-28.6%
Stanford Linear Accelerator Center	0	400	0	-400	--
Total, Oakland Operations Office	2,113	7,650	5,857	-1,793	-23.4%
Oak Ridge Operations Office					
Thomas Jefferson National Accelerator Facility	0	0	1,500	+1,500	--
Oak Ridge National Laboratory	6,627	10,745	12,016	+1,271	+11.8%
Oak Ridge Operations Office	4,112	4,479	5,079	+600	+13.4%
Total, Oak Ridge Operations Office	10,739	15,224	18,595	+3,371	+22.1%
Richland Operations Office					
Pacific Northwest National Laboratory	0	1,377	4,000	+2,623	+190.5%
Washington Headquarters	0	53	0	-53	--
Total, Science Laboratories Infrastructure	26,887 [a] [b]	37,130 [a]	42,735	+5,605	+15.1%

[a] Excludes $3,047,000 in FY 2001 and $2,880,000 in FY 2002 for Oak Ridge Landlord responsibilities transferred to Science Program Direction in FY 2003.

[b] Excludes $240,000 which was transferred to the Science Safeguards and Security program in an FY 2001 reprogramming.

Site Description

Ames Laboratory

Ames Laboratory (Ames) is located in Ames, Iowa, and is a national center for the synthesis, analysis, and engineering of rare-earth metals and their compounds. Ames conducts fundamental research in the physical, chemical, and mathematical sciences associated with energy generation and storage. The laboratory consists of 10 facilities (.32 million gross square feet of space) with the average age of the facilities being 36 years. Approximately 100 percent of the space is considered adequate.

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 139 facilities (4.6 million gross square feet of space) with the average age of the facilities being 31 years. Approximately 44 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The SLI program is currently funding the following project:

- MEL-001-17 Mechanical and Control Systems Upgrade, Phase I (TEC $9,000,000) This ongoing project will upgrade or replace 30-40 year old, deteriorated mechanical system components in various facilities. These will include HVAC, drainage, steam supply, and condensate return systems. This project will optimize capacity, enhance system reliability and performance, improve safety, and reduce maintenance costs. These systems are no longer adequate, reliable, or efficient, and do not meet current ES&H standards (e.g., failure of a laboratory exhaust system could lead to release of radioactive material).

The program also provides funding through the Chicago Operations Office for Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation.

Brookhaven National Laboratory

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The laboratory consists of 745 facilities (4.1 million gross square feet of space) with the average age of the facilities being 40 years. Approximately 35 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The SLI program is currently funding the following projects:

- MEL-001-13 Groundwater and Surface Water Protection Upgrades (TEC $6,050,000) This on-going project will address a backlog of ground and surface water protection projects which are commitments to regulators. These include: proper closure of inactive supply and injection wells; runoff control for the surplus material storage yard; containment and runoff control for the radioactive material storage yard; replacement of 12 hydraulic elevator cylinders; removal of 22 underground fuel oil tanks; and replacement of radioactive waste tanks with secondarily contained tanks.

- MEL-001-16 Electrical Systems Modifications, Phase II (TEC $6,770,000) This ongoing project is the second phase of the modernization and refurbishment of the laboratory’s deteriorating 50 year-old electrical infrastructure. The project includes: installation of two new 13.8 kV feeders to provide alternate sources to existing, aged feeders; installation of additional underground ductbanks to support a new 13.8 kV feeder; replacement of 2.4 kV switchgear to increase system reliability and safety; reconditioning of fifty 480-volt circuit breakers including replacing obsolete trip units with modern, solid-state trip devices; and the retrofit of ten 13.8 kV air breakers with new vacuum technology.

The following new project is proposed in the FY 2003 request:

- MEL-001-027 Research Support Building, Phase I (TEC $18,200,000) This 45,000 sq. ft. Research Support Building, is intended to consolidate Staff Services, Public Affairs, Human Resources, Credit Union, Library and other support functions in a central quadrangle to provide staff and visiting scientists with convenient and efficient support. This facility, the first of four phases in the BNL Master Revitalization Plan, will include a lobby with a visitor information center to assist visiting scientists, and a coordinated office layout of related support services. After completion of this project, **51,000 sq. ft. of WW II era structures will be torn down**. Based on total life-cycle costs, productivity gains, avoided energy and maintenance costs, the Research Support Building will provide a return on investment of 14.4% and a simple payback of 9 years.

The program also provides funding through the Chicago Operations Office for Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation.

Fermi National Accelerator Laboratory

Fermi National Accelerator Laboratory is a single-program laboratory leading the nation in construction and operation of large facilities for research in high-energy and particle physics. The laboratory is located in Batavia, Illinois, and consists of 447 facilities (2.2 million gross square feet of space) with the average age of the facilities being 36 years. Approximately 100 percent of the space is considered adequate.

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 176 facilities (1.7 million gross square feet of space) with the average age of the facilities being 31 years. Approximately 22 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The SLI program is currently funding the following projects:

- MEL-001-12 Site-wide Water Distribution System Upgrade (TEC $8,300,000) This ongoing project rehabilitates the Lab’s High Pressure Water (HPW) System to include: replacement of all 1.4 km of cast iron pipe with ductile iron pipe; installing cathodic protection; replacing and adding pressure reducing stations to prevent excessive system pressure at lower lab elevations; adding an emergency fire water tank to serve the East Canyon; and providing the two current emergency fire water tanks with new liners and seismic upgrades.

The following new project is proposed in the FY 2003 request:

- MEL-001-28 – Building 77 Rehabilitation of Structures and Systems, Phase II (TEC $13,360,000) This project will provide design for the rehabilitation of Building 77 to correct mechanical, electrical, and architectural deficiencies in Buildings 77 (a 68,000 sq. ft. high-bay industrial facility) and 77A (10,000 sq. ft. industrial facility). Both 33 year-old buildings house machine shop and assembly operations in which production of highly sophisticated research components for a variety of DOE research projects takes place. Current work includes precision machining, fabrication and assembly of components for the Advanced Light Source, the Dual-Axis Radiographic Hydrodynamic Test Facility (DAHRT) project, the Spallation Neutron Source, and the ATLAS Detector. Infrastructure systems installed by this project will include HVAC, power distribution, lighting, and noise absorption materials. The improvements are necessary to satisfy urgent demands for high levels of cleanliness, temperature and humidity control, and OSHA and reliability requirements. This is the second of two projects, the first project, funded in FY 1999 and currently in progress, will correct structural deficiencies in Building 77.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is an academic and training facility providing specialized scientific and safety training to DOE and other institutions. ORISE is an international leader in radiation-related emergency response and epidemiological studies. The laboratory consists of 21 facilities, 0.2 million gross square feet of space, with the average age of the facilities being 40 years. Approximately 92 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The laboratory consists of 461 facilities (4.5 million gross square feet of space) with the average age of the facilities being 31 years. Approximately 90 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The SLI program is currently funding the following projects:

- MEL-001-14 Fire Protection System Upgrade (TEC $5,920,000) This ongoing project replaces deteriorated, obsolete systems with more reliable fire alarm and suppression capabilities; replaces the single 16-inch water main in the east central section of ORNL with a looped system; and extends coverage of automatic alarm and sprinkler systems to areas not previously served. Upgrading the fire alarm receiving equipment at the site fire department headquarters ensures its reliability, modernizes its technology, and meets the demands of an expanded fire alarm system network.

- MEL-001-15 Laboratory Facilities HVAC Upgrade (TEC $7,100,000) This ongoing project provides improvements to aging HVAC systems (average age 38 years) located in the 13 buildings which comprise ORNL's central research complex and make additions and improvements to the chilled water distribution system. This includes: redesign of the cooling water distribution system to reduce the number of pumps required and installing more efficient pumps, thereby reducing operations and maintenance costs; installation of an 800 ft., 8-inch-diameter pipe, chill water cross-tie to Buildings 4501/4505 from the underground tie-line between Buildings 4500N/4509 to address low capacity problems in 4501/4505; installation of a 500 ft. 4-inch-diameter pipe to feed new chilled water coils in the east wing of Building 3500; upgrade of the existing 50 year-old air handler with new dampers, filters, steam coils, and controls; and replacement of constant volume, obsolete air handlers in various buildings with variable air volume (VAV) improvements to more efficiently control temperature.

- MEL-001-25 Research Support Center (TEC $16,100,000) This ongoing project will construct a 50,000 sq. ft. facility to house the core support service facilities and serve as the cornerstone and focal point of the East Research Campus envisioned in the ORNL Facility Revitalization Project. This building will include an auditorium and conference center (currently there is no adequate auditorium conference space available at ORNL), cafeteria, visitor reception and control area, and offices for approximately 50 people. It will facilitate consolidation of functions that are presently scattered throughout the Laboratory complex in facilities that are old (30-50 years), undersized, poorly located, or scheduled to be surplused. **This project includes removal of the 4300 sq. ft. Main Portal (Building 5000).** The facility will serve as a modern center for meeting, collaborating, and exchanging scientific ideas for ORNL staff and the nearly 30,000 visitors, guests, and collaborators that use ORNL facilities each year. The new cafeteria will replace the existing cafeteria (to be reused, possibly as a training facility), which was constructed in 1953. The existing cafeteria is poorly located to serve the current staff and is adjacent to the original production area of the lab now undergoing decontamination. The estimated simple payback is seven years.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on a 960 acre site on the south end of the Hanford Reservation near Richland, Washington. The laboratory consists of 58 facilities (0.8 million gross square feet of space) with the average age of the facilities being 30 years. Approximately 26 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The SLI program is currently funding the following project:

- MEL-001-18 Laboratory Systems Upgrades (TEC $9,000,000) This ongoing project will upgrade or replace 20-50 year old mechanical system components in eight high occupancy facilities at PNNL. This project will upgrade these obsolete systems with more efficient, better performing systems to enhance the quality of science while reducing maintenance and energy costs. This upgrade will include: replacement of HVAC supply and exhaust fans; replacement, rehabilitation or modification of numerous chemical exhaust fume hoods; installation of computerized, remote, digital controls on various systems to improve operations; and replacement of an emergency power generator.

Princeton Plasma Physics Laboratory

Princeton Plasma Physics Laboratory (PPPL) is a collaborative national center dedicated to plasma and fusion science. PPPL has a leading international role in developing the theoretical, experimental, and technology innovations needed to make fusion practical and affordable. PPPL is located in Princeton, New Jersey, and consists of 34 facilities (0.7 million gross square feet of space) with the average age of the facilities being 22 years. Approximately 89 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center (SLAC) is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California, and is the home of the Stanford Synchrotron Radiation Laboratory (SSRL). The Stanford Synchrotron Radiation Laboratory was built in 1974 to utilize the intense x-ray beams from the SPEAR storage ring that was built for particle physics by the SLAC laboratory. Over the years, the SSRL grew to be one of the main innovators in the production and use of synchrotron radiation with the development of wigglers and undulators that form the basis of all third generation synchrotron sources. The facility is now comprised of 25 experimental stations and is used each year by over 700 researchers from industry, government laboratories and universities. SLAC consists of 187 facilities (1.8 million gross square feet of space) with the average age of 22 years. Approximately 98 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition.

Thomas Jefferson National Accelerator Facility

Thomas Jefferson National Accelerator Facility (TJNAF) is a national user facility for nuclear science using continuous beams of high-energy electrons to discover the underlying quark and gluon structure of nucleons and nuclei. TJNAF has 1,600 users, about half of which are actively engaged in experiments at a given time. TJNAF is located in Newport News, Virginia, and consists of 172 facilities (.7 million gross square feet of space) with the average age of the facilities being 11 years. Approximately 89 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The SLI program proposes to fund the following new project in FY 2003:

- MEL-001-33 Continuous Electron Beam Accelerator Facility (CEBAF) Center Addition, Phase I (TEC $10,500,000) - This project is phase I of two phases to provide for an addition to the CEBAF Center office building. The purpose of the two phases is to replace off-site leased facilities and to collocate staff for enhanced productivity. This first addition will add 51,000 square feet of office space and 5,000 square feet of conference/meeting room space with a 2.7-year simple payback and a 25% rate of return. **20,000 sq.ft. of inadequate space will be vacated and removed at the conclusion of this project**. These two phases will provide additional space for 273 employees and 346 users.

Chicago Operations Office

The Chicago Operations Office processes the Payments in Lieu of Taxes made to the local taxing authorities at Brookhaven National Laboratory and Argonne National Laboratory-East.

Oak Ridge Operations Office

The Oak Ridge Landlord program provides for centralized Oak Ridge Operations Office (ORO) infrastructure requirements and general operating costs for activities on the Oak Ridge Reservation outside plant fences and activities to maintain a viable operations office, including maintenance of roads and grounds and other infrastructure, Payments In Lieu of Taxes, and other needs related to landlord activities.

Laboratories Facilities Support

Mission Supporting Goals and Objectives

This subprogram, previously titled the Multiprogram Energy - Laboratories Facilities Support (MEL-FS) subprogram, has been broadened to include SC single purpose as well as the multi-purpose laboratories and re-titled the Laboratories Facilities Support (LFS) subprogram to reflect this change.

The LFS subprogram improves the condition of laboratory buildings (i.e., increasing the percentage of buildings rated adequate) provide Payments in Lieu of Taxes (PILT) assistance for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory-East; and funds the highest priority projects by first ranking them using the Life Cycle Asset Management (LCAM) Cost-Risk-Impact Matrix that takes into account risk, impacts, and mission need. Based on these rankings, the subprogram funds the highest priority projects that reduce risk, ensure continuity of operations, avoid or reduce costs, and increase productivity.

The LFS subprogram supports the program's goal to ensure that support facilities at the Office of Science (SC) laboratories can meet the Department's research needs primarily by refurbishing or replacing deteriorated, outmoded, unsafe, and inefficient general purpose and site-wide infrastructure. General purpose and site-wide facilities are general use, service and support facilities such as administrative space, cafeterias, general office/laboratory space, utility systems, sanitary sewers, roads, etc.

Capital investment requirements for SC laboratories are identified in laboratory Strategic Facilities Plans. These ten-year site plans include priority lists of proposed facilities and infrastructure needs. These plans (currently under SC review) assume the full modernization/revitalization of the infrastructure of the labs will be completed over a ten-year period. The backlog of modernization needs is on the order of $2 billion with the unfunded portion about $1.3 billion. Of the identified infrastructure needs, nearly 85% is to rehabilitate or replace buildings.

The large backlog of building related projects reflects the fact that the condition of 53% of the laboratory space is rated adequate, while the remaining 47% needs rehabilitation or replacement/demolition. Often, even adequate space is not functional for modern research purposes (e.g., a well maintained 1940 vintage wooden barracks is not particularly useful when modern, high technology equipped lab/office or “clean room” space is needed). The large percentage of inadequate space is attributable to:

- the age of the facilities (over 69% of the buildings are 30 years old or older and, 43% are 40 years old or older)
- changing research needs that require different kinds of space (e.g., more office space and light laboratory space than hot cells)
- obsolescence of existing systems and components
- changing technology (e.g., digital controls)
- changing environmental, safety and health regulations, and
- inadequate capital investment in the past

The backlog of utilities and ES&H related projects is much lower due to previous investments by the SLI program over the last 20 years. Utilities and ES&H projects consistently scored highest in the prioritization system mentioned below and therefore received funding, while the building related projects were largely postponed.

The SLI program strives to improve the condition of laboratory buildings (i.e., increasing the percentage of buildings rated adequate based on definitions and criteria provided in the DOE corporate Facilities Information Management Systems) by increasing the percentage of facilities rated adequate over time. The percentage of space rated adequate in FY 2001 is 53%.

In any given budget year, all candidate construction projects for funding by the LFS subprogram are first ranked using the DOE Life Cycle Asset Management (LCAM) Cost-Risk-Impact Matrix 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. Based on these rankings, the subprogram funds the highest priority projects that reduce risk, ensure continuity of operations, avoid or reduce costs, and increase productivity. All FY 2001-FY 2003 funded projects were evaluated by an integrated infrastructure management team as the highest priority projects and each has a Capital Asset Management Process (CAMP) score greater than 60.

The LFS subprogram ensures that the funded projects are managed effectively and completed within the established cost, scope and schedule baselines. **Performance will be measured by** the number of all SLI projects completed within the approved baseline for cost (at or below the appropriated Total Estimated Cost), scope (within 10%), and schedule (within six months). Two projects scheduled for completion in FY 2001 were completed within the approved baselines for cost, scope, and schedule; the third was descoped due to unforeseen labor market conditions and building operational commitments that delayed completion of the project.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
General Purpose Facilities	8,816	5,380	19,107	+13,727	+255.1%
Environment, Safety and Health	12,979	16,416	12,474	-3,942	-24.0%
Payment in Lieu of Taxes (PILT)	980	895	1,020	+125	+14.0%
Total, Laboratories Facilities Support	22,775	22,691	32,601	+9,910	+43.7%

Detailed Program Justification

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		
General Purpose Facilities	**8,816**	**5,380**	**19,107**

Provides funding to support the initiation of three new subprojects in FY 2003 as well as the continuation of one FY 2001 subproject and two FY 2002 subprojects under the Science Laboratories Infrastructure (MEL-001) construction project data sheet. These are summarized below. More details are provided in the construction project data sheet presented later.

The FY 2003 funding is for design and construction activities for: 1) the LBNL Building 77 Rehabilitation of Structures and Systems, Phase II ($1,757,000); 2) BNL Research Support Building, Phase I ($3,250,000); 3) TJNAF CEBAF Center Addition, Phase I ($1,500,000). The latter two projects are for new buildings to provide 96,000 sq. ft. of modern research support space while eliminating 71,000 sq. ft. of old, deteriorated buildings that cannot be economically renovated.

The FY 2002 subprojects are the PNNL Laboratory Systems Upgrade ($4,000,000) and the ORNL Research Support Center ($5,000,000).

The FY 2001 subproject is the ORNL Laboratory Facilities HVAC Upgrade ($3,600,000).

Environment, Safety and Health...	**12,979**	**16,416**	**12,474**

Provides funding to support the continuation of one FY 2002 and four FY 2001 ES&H subprojects in the Science Laboratories Infrastructure Project (MEL-001) construction project data sheet. These are summarized below. More details are provided in the construction project data sheet presented below.

The FY 2002 subproject is the ANL-E Mechanical and Control Systems Upgrade, Phase I ($3,045,000).

The FY 2001 subprojects are: BNL Groundwater and Surface Water Protection Upgrades ($1,398,000); ORNL Fire Protection System Upgrade ($2,216,000); LBNL Site-wide Water Distribution System Upgrade ($2,900,000); and BNL Electrical Systems Modifications, Phase II ($2,915,000).

PILT	**980**	**895**	**1,020**

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Continue meeting Payments in Lieu of Taxes (PILT) assistance requirements for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory-East. PILT payment levels are negotiated between the Department and local governments. The PILT payments equaled the negotiated levels in FY 2001.			
Total, Laboratories Facilities Support....................................	**22,775**	**22,691**	**32,601**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Laboratories Facilities Support	
■ Additional funding in the General Purpose Facilities (GPF) area is to address the large backlog of infrastructure needs at all SC labs...	+13,727
■ Reduction in the Environment Safety and Health (ES&H) area (to approximately FY 2001 level) reflects the reduction in needs resulting from a significant FY 2002 ES&H investment and shifting program priorities to GPF needs	-3,942
■ Increase in funding to meet PILT requirements..	+125
Total Funding Change, Laboratories Facilities Support	+9,910

Excess Facilities Disposition

Mission Supporting Goals and Objectives

This is a new subprogram in the FY 2003 Science Laboratories Infrastructure program and will address those excess facilities needs that are the responsibility of SC as steward for the SC laboratories. In FY 2002, these funds were appropriated in a separate Facilities and Infrastructure program added by Congress.

The Excess Facilities Disposition (EFD) subprogram eliminates excess facilities at the SC laboratories to reduce long-term costs and liabilities to support programmatic initiatives (e.g. making land available for new programs). In addition to removal of excess facilities, the subprogram will also clean-up facilities for reuse where such re-use is economical and can provide needed functionality.

The subprogram supports this goal by evaluating and prioritizing the backlog of excess facilities projects that can be cleaned-up or eliminated in the next few years, which is on the order of $36,000,000. Examples of candidate projects to be undertaken are provided below. Final selection of projects to be undertaken will be based on program priorities including footprint reduction, risk reduction (e.g., removal of hazards), availability of space/land for research activities, and cost savings (e.g., elimination of surveillance and maintenance costs).

This subprogram does not address major process contaminated facilities such as research reactors that, under DOE policy, are to be transferred to the Office of Environmental Management for final disposition. Also, this subprogram does not provide for removal or replacement of "occupied" buildings (e.g., old, deteriorated and marginally functional ones that are to be replaced by new modern buildings). Such building replacement projects are funded under the previously discussed LFS subprogram and would include removal of the old buildings as part of the justification for the project.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Excess Facilities Disposition	0	9,960	5,055	-4,905	-49.2%
Total, Excess Facilities Disposition	0	9,960	5,055	-4,905	-49.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Excess Facilities Disposition	**0**	**9,960**	**5,055**

Provides operating funds to eliminate excess facilities that are no longer needed at SC laboratories and that require resources to monitor and maintain them in safe and secure conditions. FY 2002 Facilities and Infrastructure (F&I) program funding of $9,960,000 allows for the clean-up/removal of approximately 30 excess facilities. Below is a list of projects included in the FY 2002 F&I program:

- ANL-E ($810,000) – Cleanup of Building 205 Sample Carousel; cleanup of Building 315 Cell 6 Pit; cleanup of Building 315 Radiochemistry Lab (approximately 1,300 sq.ft.)

- BNL ($1,350,000) – Demolition of Building 318; demolition of Building 960 Complex; abandoned well closure and demolition of Buildings 93, 168, 915, and 917 (approximately 34,000 sq.ft.)

- LBNL ($2,500,000) – Removal of motor generators from Building 51; removal of the Heavy Ion Spectrometer System (HISS) Magnet and Structure "51G," removal of shielding blocks/beam lines from External Particle Beam (EPB) hall (approximately 21,000 sq.ft.)

- LLNL ($350,000) – Demolition and removal of the Magnetic Fusion Energy Direct Current power supply (approximately 60,000 sq.ft.)

- ORNL ($3,125,000) – Stabilization and cleanout of Building 9201-3; stabilization and cleanout of EN tandem space in Building 5500; demolition of Building 2013; demolition of Building 2506; deactivation/demolition of Building 6003 (approximately 224,000 sq.ft.)

- PNNL ($497,000) – Demolition of Building 331-B Radioactive Inhalation Facility and Dog Kennels (approximately 26,000 sq.ft.)

- SLAC ($400,000) – Demolition of the following: Building 232 - Experimental Facilities Department/Cryogenics Conference Room; Building 125 - Test Beam Facility Control Room; Building 111 – 40" Bubble Chamber Building; Building 109 – Experimental Facilities Department High Bay Building; Building 404 – Experimental Shelter; Building 133 – Stanford Linear Detector Cherenkov Ring Imaging Detector Clean Room; Building 265 – Computer Trailer; Building 295 – End Station A Office Trailer #1; Building 291 - End Station A Office Trailer #2; Building 296 – SLAC User Trailer #2; Building 297 – SLAC User Trailer #3 (approximately 13,000 sq.ft.)

- PPPL ($875,000) – Preparation for Princeton Beta Experiment Modification (PBX) Disposition (approximately 27,000 sq.ft.)

- A small amount ($53,000) is held for emergent requirements.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

In FY 2002 an estimated 400,000 total square feet of space will be removed or cleaned up for reuse.

Below is a list of projects to be undertaken in FY 2003:

- ANL-E ($1,160,000) – Building 40 (Instrument Calibration) Disposal and Partial Facility Demolition (approximately 7,000 sq. ft.)
- BNL ($950,000) – Demolition of Buildings 89, 920, 91 and 118 (approximately 32,000 sq. ft.)
- LBNL ($950,000) – Disposal of Experiment Hall concrete shield blocks, magnets, and activated components (approximately 6,000 sq. ft.)
- LLNL ($250,000) – Demolish Magnetic Fusion Energy bridge and utility lines (approximately 1,100 sq. ft.)
- ORNL ($1,200,000) – Building 1,000 deactivation/demolition (approximately 59,000 sq. ft.)
- PPPL ($545,000) – Princeton Beta Experiment Modification (PBX)/Princeton Large Torus (PLT) subsystem removals (approximately 71,000 sq. ft.)

Individual projects and amounts are subject to revision based on evolving program priorities including risk reduction (e.g., removal of hazards), footprint reduction, cost savings (e.g., elimination of surveillance and maintenance costs), and availability of space/land for new research activities.

In FY 2003, an estimated 176,000 total square feet of space will be removed or cleaned up for reuse.

	FY 2001	FY 2002	FY 2003
Total, Excess Facilities Disposition	**0**	**9,960**	**5,055**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Excess Facilities Disposition	
■ FY 2002 Excess Facilities Disposition funding was appropriated in a new program titled, "Facilities and Infrastructure." Report language directed that a minimum of 25% of the funds be used for Excess Facilities. This activity is proposed for inclusion in the SLI budget with continued funding at a reduced level in FY 2003.	-4,905
Total Funding Change, Excess Facilities Disposition	-4,905

Oak Ridge Landlord

Mission Supporting Goals and Objectives

The Oak Ridge Landlord subprogram supports activities to maintain continuity of operations at the Oak Ridge Reservation (ORR) and the Oak Ridge Operations Office (ORO) to minimize interruptions related to infrastructure and/or other systems failures.

This subprogram supports landlord responsibilities for the centralized ORR, including infrastructure of the ORR, the 24,000 acres of the Reservation outside of the Y-12 plant, ORNL, and the East Tennessee Technology Park, and DOE facilities in the town of Oak Ridge. This includes roads and grounds and other infrastructure maintenance, ES&H support and improvements, PILT for Oak Ridge communities, and other needs related to landlord requirements. These activities maintain continuity of operations at the Oak Ridge Reservation and the ORO and minimize interruptions due to infrastructure and/or other systems failures. In FY 2001 there were no significant interruptions due to infrastructure failures.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Oak Ridge Landlord	4,112	4,479	5,079	+600	+13.4%

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
■ **Roads, Grounds and Other Infrastructure and ES&H Support and Improvements**	**2,000**	**2,200**	**2,488**
■ **Payments in Lieu of Taxes (PILT)**	**1,900**	**1,900**	**2,300**
Payments in Lieu of Taxes (PILT) to the City of Oak Ridge, and Anderson and Roane Counties.			
■ **Reservation Technical Support**	**212**	**379**	**291**
Includes recurring activities such Site Mapping, National Archives Records Administration, and support for legacy legal cases.			
Total, Oak Ridge Landlord	**4,112**	**4,479**	**5,079**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Oak Ridge Landlord	
▪ Increases the Roads, Grounds and Other Infrastructure and ES&H Support and Improvements to more aggressively address deficiencies and expected increase in traffic due to the Spallation Neutron Source project.	+288
▪ Supports the negotiated increase in the per acre value of land used to calculate the PILT payment.	+400
▪ Maintain ORR technical support at approximately the FY 2002 level.	-88
Total Funding Change, Oak Ridge Landlord	+600

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
General Plant Projects (ORO Landlord)........	0	0	0	0	--
Capital Equipment (ORO Landlord)	0	0	0	0	--
Total, Capital Operating Expenses	0	0	0	0	--

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2001	FY 2002	FY 2003	Unapprop. Balance
Project – 02-SC-001 Laboratories Facilities Support Project FY 2002 PED Datasheet......................	N/A	N/A	0	3,183	0	0
Project – 03-SC-001 Laboratories Facilities Support Project FY 2003 PED Datasheet......................	N/A	N/A	0	0	3,355	0
Project - MEL-001 Laboratories Facilities Support Project FY 2003 Construction Datasheet..........	N/A	N/A	21,795	18,613	28,226	54,425
Total, LFS Construction..............................	N/A	N/A	21,795	21,796	31,581	54,425

03-SC-001 – Science Laboratories Infrastructure, Project Engineering Design (PED), Various Locations

1. Construction Schedule History

Fiscal Quarter				Total Estimated 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
2003	3,355	3,355	2,775
2004	0	0	580

3. Project Description, Justification and Scope

This project funds PED for two types of subprojects:

- Projects that renovate or replace inefficient and unreliable general purpose facilities (GPF) including general use, service and support facilities such as administrative space, cafeterias, utility systems, and roads; and
- Projects to correct Environment, Safety and Health (ES&H) deficiencies including deteriorated steam lines, environmental insult, fire safety improvements, sanitary system upgrades and electrical system replacements.

This PED data sheet requests design funding for three FY 2003 new starts: Lawrence Berkeley National Laboratory; Building 77 Rehabilitation of Structures and Systems, Phase II; Brookhaven National Laboratory Research Support Building, Phase I; and the Thomas Jefferson National Accelerator Facility Continuous Electron Beam Accelerator Facility (CEBAF) Center Addition, Phase I.

FY 2003 Proposed Design Projects

General Purpose Facilities Projects:

03 -01: MEL-001-028 – Building 77 Rehabilitation of Structures and Systems, Phase II (LBNL)

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2003	2Q 2004	3Q 2004	N/A	1,100	13,360

Fiscal Year	Appropriations	Obligations	Costs
2003	1,100	1,100	820
2004	0	0	280

This design project will provide design for the rehabilitation of Building 77 to correct mechanical, electrical and architectural deficiencies in Buildings 77 (a 68,000 sq. ft. high-bay industrial facility) and 77A (10,000 sq. ft. industrial facility). Both 33 year-old buildings house machine shop and assembly operations in which production of highly sophisticated research components for a variety of DOE research projects takes place. Current work includes precision machining, fabrication and assembly of components for the Advanced Light Source, the Dual-Axis Radiographic Hydrodynamic Test Facility (DAHRT) project, the Spallation Neutron Source, and the ATLAS Detector. Infrastructure systems installed by this project will include HVAC, power distribution, lighting, and noise absorption materials. The improvements are necessary to satisfy urgent demands for high levels of cleanliness, temperature and humidity control, and OSHA and reliability requirements. This is the second of two projects, the first project, funded in FY 1999 and currently in progress, will correct structural deficiencies in Building 77.

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

03 -02: MEL-001-027 – Research Support Building, Phase I (BNL)

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2003	2Q 2004	3Q 2004	N/A	1,710	18,200

Fiscal Year	Appropriations	Obligations	Costs
2003	1,710	1,710	1,410
2004	0	0	300

This design project will provide design for construction of the Research Support Building, Phase I. This 45,000 sq.ft. Research Support Building is intended to consolidate Staff Services, Public Affairs, Human Resources, Credit Union, Library and other support functions in a central quadrangle to provide staff and visiting scientists with convenient and efficient support. This facility, the first of four phases in the BNL Master Revitalization Plan, will include a lobby with a visitor information center to assist visiting scientists, and a coordinated office layout of related support services. After completion of this project, 51,000 sq. ft. of WWI era structures will be torn down. Based on total life-cycle costs, productivity gains, avoided energy and maintenance costs, the Research Support Building will provide a return on investment of 14.4% and a simple payback of 9 years.

03 -03: MEL-001-033 – CEBAF Center Addition, Phase I (TJNAF)

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2003	4Q 2003	1Q 2004	N/A	545	10,500

Fiscal Year	Appropriations	Obligations	Costs
2003	545	545	545

This design project will provide design for Phase I of two phases to provide for an addition to the CEBAF Center office building. The purpose of the two phases is to eliminate inadequate space, replace off-site leased facilities and to collocate staff for enhanced productivity. The first addition will add 51,000 square feet of office space and 5,000 of conference/meeting room space with a 2.7-year simple payback and a 25% rate of return. 20,000 sq. ft. of inadequate space will be vacated and removed at the conclusion of this project. These two phases will provide additional space for 273 employees and 346 users.

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

Ongoing PED Design Projects

(dollars in thousands)

(Design Project No. PED-02-SC-001) Multiprogram Energy Laboratories, Project Engineering Design (PED), Various Locations	Location	Design TEC	Approp. to Date	Obligs. to Date	Costs to Date	Design Start	Design Completion	Constr. Status (Fiscal Year)
General Purpose Facilities Projects:								
02-01: MEL-001-018 Lab. Systems Upgrade	PNNL	880	880	0	0	1Q2002	3Q2003	2Q2003

This design project will provide design to upgrade or replace 20-50 year old mechanical system components in eight high occupancy facilities at PNNL. This project will upgrade these obsolete systems with more efficient, better performing systems to enhance the quality of science while reducing maintenance and energy costs. This upgrade will include: replacement of HVAC supply and exhaust fans; replacement, rehabilitation or modification of numerous chemical exhaust fume hoods; installation of computerized, remote, digital controls on various systems to improve operations; and replacement of an emergency power generator.

02-03: MEL-001-025 Research Support Center	ORNL	1,500	1,500	0	0	1Q2002	3Q2003	2Q2003

This design project will construct a 50,000 sq. ft. facility to house the core support service facilities and serve as the cornerstone and focal point of the East Research Campus envisioned in the ORNL Facility Revitalization Project. This building will include an auditorium and conference center (currently there is no adequate auditorium/conference space available at ORNL), cafeteria, visitor reception and control area, and support offices for approximately 50 occupants. It will facilitate consolidation of functions, which are presently scattered throughout the Laboratory complex in facilities that are old (30-50 years), undersized, poorly located, or scheduled for surplus. This project will include removal of the 4300 sq. ft. Main Portal (Building 5000). The facility will serve as a modern center for meeting, collaborating, and exchanging scientific ideas for ORNL staff and the nearly 30,000 visitors, guests, and collaborators that use ORNL facilities each year. The new cafeteria will replace the existing cafeteria (to be reused, possibly as a training center), which was constructed in 1953. The existing cafeteria is poorly located to serve the current staff and is adjacent to the original production area of the lab now undergoing decontamination. The estimated simple payback is seven years.

(Design Project No. PED-02-SC-001) Multiprogram Energy Laboratories, Project Engineering Design (PED), Various Locations	Location	Design TEC	Approp. to Date	Obligs. to Date	Costs to Date	Design Start	Design Completion	Constr. Status (Fiscal Year)
ES&H Projects:								
02-08: MEL-001-017 Mechanical Control Systems Upgrade, Ph. I	ANL	803	803	0	0	1Q2002	3Q2003	2Q2003

This design project will provide design to upgrade and replace 30-40 year old mechanical system components in various facilities. It will optimize capacity, enhance system reliability and performance, improve safety, and reduce maintenance and repair costs of primary building mechanical equipment and control systems. The mechanical systems designated for replacement are no longer adequate, reliable, or efficient, and do not meet current ES&H standards (i.e. failure of laboratory exhaust systems could lead to the release of radioactive material). Specifically, this project will: upgrade HVAC systems in Bldgs. 221 and 362, including heating and cooling coils, fans, filter systems, ductwork, controls, and variable frequency drive fans; upgrade lab exhaust systems in Bldgs. 202 and 306, including new fans, ductwork, and controls; upgrade corroded drainage systems in Bldgs. 200, 205 and 350; and upgrade steam and condensate return systems in 12 facilities in the 360 area. This will include high and low pressure steam supply piping and associated pressure reducing stations, valves, and accessories; and replacing condensate pumping systems including piping, valves and system controls.

FY 2002 Total		3,183	3,183	0	0

4. Details of Cost Estimate

N/A

5. Method of Performance

Design services will be obtained through competitive and/or negotiated contracts. M&O contractor staff may be utilized in areas involving security, production, proliferation, etc. concerns.

6. Schedule of Project Funding

N/A

MEL-001 – Science Laboratories Infrastructure Project, Various Locations

(Changes from FY 2002 Congressional Budget Request are denoted with a vertical line in the left margin.)

Significant Changes

None

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
Project Engineering & Design (PED)			
FY 2002	3,183 [a]	3,183	2,385
FY 2003	3,355 [b]	3,355	3,573
FY 2004	0	0	580
Construction			
Prior Years	21,114	21,114	7,680
FY 2001	21,795	21,795	17,900
FY 2002	18,613	18,613	12,450
FY 2003	28,226	28,226	27,445
FY 2004	30,622	30,622	35,500
FY 2005	23,803	23,803	27,500
FY 2006	0	0	12,000
FY 2007	0	0	3,698

[a] Title I and Title II Design funding of $880,000 (Subproject 18); $803,000 (Subproject 17); and $1,500,000 (Subproject 25) requested under Project Engineering Design (PED) Project No. 02-SC-001.

[b] Title I and Title II Design funding of $1,710,000 (Subproject 27); $1,100,000 (Subproject 28); $545,000 (Subproject 33) requested under Project Engineering Design (PED) Project No. 03-SC-001.

3. Project Description, Justification and Scope

This project funds two types of subprojects:

- Projects that renovate or replace inefficient and unreliable general purpose facilities (GPF) including general use, service and support facilities such as administrative space, cafeterias, utility systems, and roads; and
- Projects to correct Environment, Safety, and Health (ES&H) deficiencies including deteriorated steam lines, environmental insult, fire safety improvements, sanitary system upgrades and electrical system replacements.

General Purpose Facilities Projects:

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

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
5,730	4,730	1,000	0	0	0	2Q 2000 - 4Q 2001

This project is the first phase of a planned modernization and refurbishment of the Laboratory's electrical infrastructure. The project provides for the replacement of 30 to 50 year old deteriorating underground electrical cables, the addition of underground ductbanks to replace damaged portions and support new cabling, the installation of a new 13.8 kV - 2.4 kV step-down transformer substation to address capacity and operational problems, and the retrofitting/reconditioning of switchgear power circuit breakers.

b. Subproject 05 - Bldg. 77 - Rehabilitation of Building Structure and Systems (LBNL)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
8,000	6,887	1,113	0	0	0	3Q 2000 - 2Q 2002

This project will rehabilitate Building 77's structural system to restore lateral force resistance and arrest differential foundation settlement. These upgrades will restore this 33 year-old, 68,000 sq.ft. building to acceptable seismic performance and prevent loss at this facility due to structure failures.

c. Subproject 06 - Central Supply Facility (ANL-E)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
5,900	5,240	660	0	0	0	3Q 2000 – 4Q 2001

This project includes a 22,000 sq.ft. addition to the Transportation and Grounds Facility (Bldg. 46) along with remodeling of 3,500 sq.ft. of space in the existing Transportation and Grounds Facility. The project will result in economies and efficiencies by providing a highly efficient and cost-effective consolidated facility to meet the missions of the Materials Group and the Property Group of ANL-East and will eliminate the need for 89,630 square feet of substandard (50 year-old) space in ssix 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.

d. Subproject 08 - Electrical Systems Upgrade (ORNL)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
5,900	357	5,543	0	0	0	3Q 2001 - 2Q 2003

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.

e. Subproject 15 – Laboratory Facilities HVAC Upgrade (ORNL)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
7,100	0	500	3,000	3,600	0	3Q 2002 – 2Q 2004

This project will provide improvements to aging HVAC systems (average age 38 years) located in the thirteen (13) buildings which comprise Oak Ridge National Laboratory's (ORNL's) central research complex and additions and improvements to the chiller water distribution system. This includes: redesign of the cooling water distribution system to reduce the number of pumps required and installing more efficient pumps, thereby reducing operations and maintenance costs; installation of an 800 ft., 8-inch-diameter pipe, chill water cross-tie to Bldgs. 4501/4505 from the underground tie-line between Bldgs. 4500N/4509 to address low capacity problems in 4501/4505; installation of a 500 ft. 4-inch-diameter pipe to feed new chilled water coils in the east wing of Bldg. 3500; upgrade of the existing 50 year-old air handler with new dampers, filters, steam coils, and controls; and replacement of constant volume, obsolete air handlers in various buildings with variable air volume (VAV) improvements to more efficiently control temperature.

f. Subproject 18 – Laboratory Systems Upgrades (PNNL)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
9,000	0	0	880 [a]	4,000	4,120	2Q 2003 – 2Q 2005

This project will upgrade or replace 20-50 year old mechanical system components in eight high occupancy facilities at PNNL. This project will upgrade these obsolete systems with more efficient, better performing systems to enhance the quality of science while reducing maintenance and energy costs. This upgrade will include: replacement of HVAC supply and exhaust fans; replacement, rehabilitation or modification of numerous chemical exhaust fume hoods; installation of computerized, remote, digital controls on various systems to improve operations; and replacement of an emergency power generator.

g. Subproject 25 – Research Support Center (ORNL)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
16,100	0	0	1,500 [a]	5,000	9,600	2Q 2003 – 2Q 2005

This project will construct a 50,000 sq. ft. facility to house the core support service facilities and serve as the cornerstone and focal point of the East Research Campus envisioned in the ORNL Facility Revitalization Project. This building will include an auditorium and conference center (currently there is no adequate auditorium/conference space available at ORNL), cafeteria, visitor reception and control area, and offices for approximately 50 people. It will facilitate consolidation of functions,

[a] Title I and Title II Design funding requested under Project Engineering Design (PED) Project No. 02-SC-001.

which are presently scattered throughout the Laboratory complex in facilities that are old (30-50 years), undersized, poorly located, or scheduled to be surplused. This project will include removal of the 4300 sq. ft. Main Portal (Building 5000). The facility will serve as a modern center for meeting, collaborating, and exchanging scientific ideas for ORNL staff and nearly 30,000 visitors, guests, and collaborators that use ORNL facilities each year. The new cafeteria will replace the existing cafeteria (to be reused, possibly as a training facility), which was constructed in 1953. The existing cafeteria is poorly located to serve the current staff and is adjacent to the original production area of the lab now undergoing decontamination. The estimated simple payback is seven years.

h. Subproject 27 – Research Support Building , Phase I (BNL)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
18,200	0	0	0	3,250 [a]	14,950	1Q 2004 – 3Q 2006

This project will construct a 45,000 sq. ft. facility to consolidate Staff Services, Public Affairs, Human Resources, Credit Union, Library, and other support functions in a central quadrangle to provide staff and visiting scientists with convenient and efficient support. This facility, the first of four phases in the BNL Master Revitalization Plan, will include a lobby with a visitor information center to assist visiting scientists, and a coordinated office layout of related support services. After completion of this project, 51,000 sq. ft. of WWII era structures will be torn down. Based on total life-cycle costs, productivity gains, avoided energy and maintenance costs, the Research Support Building will provide a return on investment of 14.4% and a simple payback of 9 years.

i. Subproject 28 – Building 77 Rehabilitation of Structures and Systems, Phase II (LBNL)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
13,360	0	0	0	1,757 [b]	11,603	2Q 2004 – 2Q 2006

This project will provide for the rehabilitation of Building 77 to correct mechanical, electrical and architectural deficiencies in Buildings 77 (a 68,000 sq.ft. high-bay industrial facility) and 77A (10,000 sq.ft.industrial facility). Both 33 year-old buildings house machine shop and assembly operations in which production of highly sophisticated research components for a variety of DOE research projects takes place. Current work includes precision machining, fabrication and assembly of components for the Advanced Light Source, the Dual-Axis Radiographic Hydrodynamic Test Facility (DAHRT) project, the Spallation Neutron Source, and the ATLAS Detector. Infrastructure systems installed by this project will include HVAC, power distribution, lighting, and noise absorption materials. The improvements are necessary to satisfy urgent demands for high levels of cleanliness, temperature and humidity control, and OSHA and reliability requirements. This is the second of two projects, the first project, funded in FY99 and currently in progress, will correct structural deficiencies in Bldg. 77.

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[a] Title I and Title II Design funding of $1,710,000 requested under Project Engineering Design (PED) Project No. 03-SC-001.

[b] Title I and Title II Design funding of $1,100,000 requested under Project Engineering Design (PED) Project No. 03-SC-001.

j. Subproject 33 – Continuous Electron Beam Accelerator Facility (CEBAF) Center Addition, Phase I (TJNAF)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
10,500	0	0	0	1,500[a]	9,000	4Q 2003 – 4Q 2005

This project will construct Phase I of two phases to provide for an addition to the CEBAF Center office building. The purpose of the two phases is to eliminate inadequate space, replace off-site leased facilities and to collocate staff for enhanced productivity. This first addition will add 51,000 sq. ft. of office space and 5,000 of conference/meeting room space with a 2.7-year simple payback and a 25% rate of return. 20,000 sq. ft of inadequate space will be vacated and removed at the conclusion of this project. These two phases will provide additional space for 273 employees and 346 users

ES&H Projects:

a. Subproject 07 - Sanitary System Modifications, Phase III, (BNL)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
6,500	3,500	3,000	0	0	0	1Q 2000 - 2Q 2002

The BNL Sanitary System consists of over 20 miles of collection piping that collects sanitary waste from nearly all the BNL facilities. The collection piping transports the waste via gravity piping and lift stations to a sewage treatment plant (STP). This project is the third phase of the upgrade of the Laboratory sanitary waste system. In the first two phases, major operations of the STP were upgraded and approximately 14,000 feet of trunk sewer lines were replaced, repaired, or lined. Phase III will continue this upgrade and will replace or rehabilitate approximately 9,900 feet of existing deteriorated (8 to 20 inch) sewer piping, connect five facilities to the sanitary system by installing 7,500 feet of new sewer pipe, and two new lift stations. This will eliminate non-compliant leaching fields and cess pools, reduce non-contact cooling water flow into the sewage system by 72 million gallons per year by: diverting flow to the storm system; converting water heat exchangers to air cooled condensers; and replacing water cooled equipment in 15 buildings. The STP anaerobic sludge digester will be replaced with an aerobic sludge digester to eliminate high maintenance activity and improve performance.

[a] Title I and Title II Design funding of $545,000 requested under Project Engineering Design (PED) Project No. 03-SC-001.

b. Subproject 09 - Fire Safety Improvements, Phase IV (ANL-E)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
8,381	400	5,951	2,030	0	0	3Q 2001 - 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.

c. Subproject 12 - Site-wide Water Distribution System Upgrade (LBNL)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
8,300	0	1,000	4,400	2,900	0	2Q 2002 – 1Q 2004

This project will rehabilitate the Laboratory's High Pressure Water (HPW) System that supplies over 100 facilities at LBNL. The HPW System provides domestic water, fire water, treated water, cooling tower water and low conductivity water. It consists of 9.6 km of pipe (1.4 km of cast iron pipe, 6.3 km of ductile iron pipe, and 1.9 km of cement lined coated steel pipe), associated valves, pumps, fittings etc. and two 200,000 gallon emergency fire water tanks. This project will: replace all cast iron pipe, which is in imminent danger of failing, with ductile iron pipe; electrically isolate pipe and provide cathodic protection; replace leaking valves and add pressure reducing stations to prevent excessive system pressure at lower lab elevations; add an emergency fire water tank to serve the East Canyon; and provide the two current emergency fire water tanks with new liners and seismic upgrades.

d. Subproject 13 - Groundwater and Surface Water Protection Upgrades (BNL)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
6,050	0	1,889	2,763	1,398	0	2Q 2002 - 1Q 2004

This project will implement a backlog of ground and surface water protection projects that are commitments to regulators. These include: proper closure of inactive supply and injection wells; runoff control for the surplus material storage yard; containment and runoff control for the radioactive material storage yard; replacement of 12 hydraulic elevator cylinders; removal of 22 underground fuel oil tanks; and other Suffolk County Article 12 upgrades.

e. Subproject 14 - Fire Protection System Upgrade (ORNL)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
5,920	0	584	3,120	2,216	0	3Q 2002 - 4Q 2004

This project will upgrade the 36 year-old fire protection system with improved, more reliable fire alarm and suppression capabilities by: replacing deteriorated, obsolete systems; replacing the single 16-inch water main in the east central section of ORNL with a looped system (7,000 lf of 16 inch pipe); and by extending coverage of automatic alarm systems to areas not previously served. New fire alarm equipment will provide emergency responders with greatly improved annunciation of the causes and locations of alarms and will provide code compliant occupant notification evacuation alarms for enhanced life safety. It will also include timesaving, automatic diagnostic capabilities that will reduce maintenance costs. The new occupant notification systems will comply with the Americans with Disabilities Act. The fire alarm receiving equipment at the site fire department headquarters will be upgraded to ensure its reliability, modernize its technology, and meet the demands of an expanded fire alarm system network.

f. Subproject 16 – Electrical Systems Modifications, Phase II (BNL)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
6,770	0	555	3,300	2,915	0	2Q 2002 – 1Q 2004

This project is the second phase of the modernization and refurbishment of the Laboratory's deteriorating 50 year-old electrical infrastructure. The project includes: installation of two new 13.8 kV feeders to provide alternate sources to existing, aged feeders; installation of additional underground ductbanks to support a new 13.8 kV feeder; replacement of 2.4 kV switchgear to increase system reliability/safety; reconditioning of 50 480-volt circuit breakers including replacing obsolete trip units with modern, solid-state trip devices; and the retrofit of 10 13.8 kV air breakers with new vacuum technology.

g. Subproject 17 – – Mechanical and Control Systems Upgrade, Phase I (ANL-E)

TEC	Prev.	FY 2001	FY 2002	FY 2003	Outyear	Construction Start/ Completion Dates
9,000	0	0	803 [a]	3,045	5,152	3Q 2003 – 3Q 2005

This design project will provide design to upgrade and replace 30-40 year old mechanical system components in various facilities. It will optimize capacity, enhance system reliability and performance, improve safety, and reduce maintenance and repair costs of primary building mechanical equipment and control systems. The mechanical systems designated for replacement are no longer adequate, reliable, or efficient, and do not meet current ES&H standards (i.e. failure of

[a] Title I and Title II Design funding requested under Project Engineering Design (PED) Project No. 02-SC-001.

laboratory exhaust systems could lead to the release of radioactive material). Specifically, this project will: upgrade HVAC systems in Bldgs. 221 and 362, including heating and cooling coils, fans, filter systems, ductwork, controls, and variable frequency drive fans; upgrade lab exhaust systems in Bldgs. 202 and 306, including new fans, ductwork, and controls; upgrade corroded drainage systems in Bldgs. 200, 205 and 350; and upgrade steam and condensate return systems in 12 facilities in the 360 area. This will include high and low pressure steam supply piping and associated pressure reducing stations, valves, and accessories; and replacing condensate pumping systems including piping, valves and system controls.

4. Details of Cost Estimate

N/A

5. Method of Performance

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

8. Design and Construction of Federal Facilities

All DOE facilities are designed and constructed in accordance with applicable Public Laws, Executive Orders, OMB Circulars, Federal Property Management Regulations, and DOE Orders. The total estimated cost of the project includes the cost of measures necessary to assure compliance with Executive Order 12088, "Federal Compliance with Pollution Control Standards;" section 19 of the Occupational Safety and Health Act of 1970, the provisions of Executive Order 12196, and the related Safety and Health provisions for Federal Employees (CFR Title 29, Chapter XVII, Part 1960); and the Architectural Barriers Act, Public Law 90-480, and implementing instructions in 41 CFR 101-19.6. The project will be located in an area not subject to flooding determined in accordance with Executive Order 11988. DOE has reviewed the GSA inventory of Federal Scientific laboratories and found insufficient space available, as reported by the GSA inventory.

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Fusion Energy Sciences

Program Mission

The Fusion Energy Sciences (FES) program leads the national research effort to advance plasma science, fusion science, and fusion technology—the knowledge base needed for an economically and environmentally attractive fusion energy source. Fusion offers the potential for abundant, safe, environmentally attractive, affordable energy. The science and the technology of fusion have progressed to the point that the next major research step is the exploration of the physics of a self-sustained plasma reaction in a burning plasma physics experiment. The Office of Science (SC) will fund research that supports such an experiment. In addition, SC will fund the exploration of innovative approaches to confining, heating, and fueling plasmas. In order to develop a predictive capability to design future fusion experiments and energy systems, unique, state-of-the-art experiments and theoretical models benchmarked against those experiments will be funded by SC. The characteristics of the materials used in the construction of fusion power plants will determine the environmental impact that those power plants will have on the environment. SC will support scientific research aimed at developing materials for fusion applications in coordination with its basic materials science program that will ensure that fusion-generated power will have a minimal environmental impact. SC will support and sustain basic plasma science research as the vital scientific core of the fusion program.

Strategic Objectives

SC6: Advance the fundamental understanding of plasma, the fourth state of matter, and enhance predictive capabilities, through the comparison of well-diagnosed experiments, theory and simulation; for Magnetic Fusion Energy (MFE), resolve outstanding scientific issues and establish reduced-cost paths to more attractive fusion energy systems by investigating a broad range of innovative magnetic confinement configurations; advance understanding and innovation in high-performance plasmas, optimizing for projected power-plant requirements; develop enabling technologies to advance fusion science, pursue innovative technologies and materials to improve the vision for fusion energy; and apply systems analysis to optimize fusion development; for Inertial Fusion Energy (IFE), leveraging from the Inertial Confinement Fusion (ICF) program sponsored by the National Nuclear Security Agency's (NNSA) Office of Defense Programs, advance the fundamental understanding and predictability of high energy density plasmas for IFE.

SC7: Provided major advanced scientific user facilities where scientific excellence is validated by external review; average operational downtime does not exceed 10% of schedule; construction and upgrades are within 10% of schedule and budget; and facility technology research and development programs meet their goals.

Progress toward accomplishing these Strategic Objectives will be measured by Program Strategic Performance Goals, Indicators and Annual Targets, as follows:

Program Strategic Performance Goals

SC6-1: Develop the basis for a reliable capability to predict the behavior of magnetically confined plasma and use the advances in the Tokamak concept to enable the start of the burning plasma physics phase of the U.S. fusion sciences program. (Science subprogram)

Performance Indicator

The range of parameter space over which theoretical modeling and experiments agree.

Performance Standards

As discussed in Corporate Context/Executive Summary.

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Improved nonlinear magneto-hydrodynamics codes to be capable of computing the effect of realistic resistive walls and plasma rotation on advanced tokamak pressure limits. (met goal)	Use recently upgraded plasma microwave heating system and new sensors on DIII-D to study feedback stabilization of disruptive plasma oscillations.	Complete installation of internal coils for feedback control of plasma instabilities on DIII-D, and conduct a first set of experiments demonstrating the effectiveness of these coils in controlling plasma instabilities, and compare with theoretical predictions.
Evaluated first physics results from the innovative Electric Tokamak at UCLA, to study fast plasma rotation and associated radial electric fields due to radiofrequency-drive, in order to enhance plasma pressure in sustained, stable plasmas. (Exploratory Concept-Electric Tokamak) (met goal)	Successfully demonstrate innovative techniques for initiating and maintaining current in a spherical torus.	Produce high temperature plasmas with 5 Megawatts of Ion Cyclotron Radio Frequency (ICRF) power for pulse lengths of 0.5 seconds in Alcator C-Mod. Study the stability and confinement properties of these plasmas, which would have collisionalities in the same range as that expected for the burning plasma regime.

SC6-2: Develop the cutting edge technologies that enable FES research facilities to achieve their scientific goals and investigate innovations needed to create attractive visions of designs and technologies for fusion energy systems. (Enabling R&D subprogram)

Performance Indicator

Percentage of milestones met for installing components developed by the Enabling R&D program on existing experimental devices.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Completed the DOE-Japan Atomic Energy Research Institute collaboration on fusion plasma chamber exhaust processing in the Tritium Systems Test Assembly (TSTA) facility at LANL. (met goal)	Complete design and fabrication of the High-Power Prototype advanced ion-cyclotron radio frequency antenna that will be used at the Joint European Torus (JET).	Complete testing of the High-Power Prototype advanced ion-cyclotron radio frequency antenna that will be used at the Joint European Torus.
Initiated a new U.S.-Japan collaborative program for research on enabling technologies, materials, and engineering science for an attractive fusion energy source. (met goal)	Complete measurements and analysis of thermal creep of Vanadium Alloy (V-4Cr-4Ti) in vacuum and lithium environments, determine controlling creep mechanisms and access operating temperature limits.	Complete preliminary experimental and modeling investigations of nano-scale thermodynamic, mechanical, and creep-rupture properties of nanocomposited ferritic steels.

SC7-6: Manage all FES facility operations and construction to the highest standards of overall performance, using merit evaluation and independent peer review. (Facility Operations subprogram)

Performance Indicator

Percent on time/on budget, percent unscheduled downtime.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Kept deviations in cost and schedule for upgrades and construction of scientific user facilities within 10 percent of approved baselines; achieved planned cost and schedule performance for dismantling, packaging, and offsite shipping of the Tokamak Fusion Test Reactor (TFTR) systems [Met Goal]	Keep deviations in cost and schedule for upgrades and construction of scientific user facilities within 10 percent of approved baselines; successfully complete within cost and in a safe manner all TFTR decontamination and decommissioning activities.	Keep deviations in cost and schedule for upgrades and construction of scientific user facilities within 10 percent of approved baselines; complete the National Compact Stellarator Experiment (NCSX) Conceptual Design and begin the Preliminary Design.
Kept deviations in weeks of operation for each major facility within 10 percent of the approved plan. [Met Goal]	Keep deviations in weeks of operation for each major facility within 10 percent of the approved plan.	Keep deviations in weeks of operation for each major facility within 10 percent of the approved plan.

Significant Accomplishments and Program Shifts

Science

SCIENCE ACCOMPLISHMENTS

Research funded by the Fusion Energy Sciences program in FY 2001 produced major scientific results over a wide range of activities. Examples of these results include:

- Enhanced Understanding of Electric Currents in a Plasma—Experiments on controlling electric currents in the plasma with high-power microwaves on DIII-D have demonstrated the predicted improvement in the efficiency of this process with increased plasma pressure, and achieved the efficiency that is required for future "advanced tokamak" experiments. The same microwave system was also used to eliminate a class of instabilities that otherwise limit the achievable plasma pressure in these "advanced" operating modes.
- Improvements in High Harmonic Fast Wave Heating—This heating technique has emerged as a powerful control tool on National Spherical Torus Experiment (NSTX). This form of wave heating now permits new operating scenarios with overall improvements in plasma heating effectiveness.
- Improvements in Controlling Plasma Heating—Researchers have continued to work on a powerful tool for creating and manipulating desired "internal transport barriers" which prevent unwanted heat leakage from magnetically confined fusion plasmas. At the Alcator C-Mod, researchers have developed a technique known as "off-axis ion cyclotron radio frequency heating," which can produce a clean transport barrier in the core. Using multiple frequencies, it is now found that the evolution of the transport barrier can be controlled and the potential for steady-state operation has been demonstrated.
- Reduction in Energy Transport—Greatly reduced energy transport has been achieved in the Reversed Field Pinch (RFP), an innovative confinement concept experiment at the University of Wisconsin. Optimization of the current-profile has further improved confinement so that the global energy confinement time is now nine times that of a standard RFP plasma. This confinement significantly exceeds the empirical scaling that has characterized this fusion concept for several decades.
- Enhanced Plasma Control System on DIII-D — As plasma pressure increases, the plasma itself can cause deformations of the magnetic field configuration, which very rapidly destroy the plasma confinement. Theoretical predictions indicated that a perfectly conducting wall surrounding the plasma can improve its stability. It was also believed that when the plasma spins rapidly, an ordinary metallic wall should have the same stabilizing properties of a perfectly conducting wall. Recent experiments at DIII-D by a collaborative team of scientists from General Atomics, Columbia University and Princeton Plasma Physics Laboratory have made use of new plasma control systems to improve stability. The control system detects and opposes deformations of the plasma in much the same way that a superconducting wall would; it also automatically corrects small irregularities in the magnetic field, which would otherwise tend to have a "braking" effect on the rotation of the plasma. With the new control system, the plasma pressure was increased stably up to levels almost twice as high as allowed in absence of such control. These results are potentially important for the development of steady-state advanced tokamaks, and may allow these devices to operate stably well above the conventional pressure limit if plasma rotation can be maintained.

- A Novel Operating Mode on Alcator C-Mod—The Enhanced D-alpha (EDA) operating mode first seen on Alcator C-Mod exhibits many promising features, such as excellent energy confinement, while exhibiting neither accumulation of impurities nor the occurrence of large edge oscillations. New and very accurate measurements have revealed that the density and electric field fluctuations, from a quasi-coherent oscillation, drive particle transport across magnetic field lines. These results together with ongoing theoretical efforts provide insight with regard to the physics of this very promising mode of operation for future machines.

- Development of Turbulence Modeling Computer Codes—Simulation codes containing turbulence computer models, in which plasma is represented by charged particles, including an improved physics model for the behavior of electrons, have been developed. Calculations using the code show that electron dynamics affect plasma stability in the presence of variations in ion temperature along the plasma radius. Previously, the system was modeled by electrons with simplified physics. It was shown that electrons are also responsible for instabilities due to variations in electron temperature. This research permits much more realistic modeling of transport.

- Improvements in Computer Modeling of the Plasma Edge—Recent improvements in computer modeling of edge turbulence have made it possible to simulate the transition from low confinement mode to high confinement mode in a tokamak. The models not only reproduce the main aspects of the transition, but also reproduce the sizes and frequencies of the turbulent regions that are in agreement with the experimental data.

- Advances in Understanding IFE Beam Transport—How a heavy ion driver beam is transported and focused in a target chamber must be known with high confidence because of the impact this information has on both target requirements and the beam that must be produced by the accelerator. Initial efforts directed toward this problem, including beam neutralization, have been carried out by upgrading existing facilities at LBNL and beginning development of a new plasma source conceived at PPPL.

- A New Research Device for Addressing IFE Development—One of the scientific and technical challenges to development of heavy ion drivers for IFE is the production of intense beams. A new 500-kilovolt test-stand was completed at LLNL and will be used for experiments to provide better understanding of the physics that determines how the necessary beam intensities can be generated. These experiments will provide the basis for new ion sources to be used in future high current experiments.

- Operation of a New Plasma Source—A coaxial magnetized plasma gun (spheromak source) with unconventional design has been constructed at Caltech and is now operational. The new gun emphasizes geometric simplicity to provide insight into a novel startup mechanism and spheromak formation. This method allows one to dispense with the large, expensive high voltage insulators used in traditional designs.

- Initial Operation of an Advanced Stellarator—The Helical Symmetric Experiment (HSX), the first advanced stellarator in the world to test quasi-symmetry, is completing its first year of plasma operations at the University of Wisconsin. Well-formed nested magnetic surfaces have been observed, and a method has been developed and applied to experimentally measure the magnitude of the magnetic field.

- Initial Operation of a New Field Reversed Configuration Experiment—The Translation, Confinement, & Sustainment (TCS), Field Reversed Configuration (FRC) experiment became fully operational at the University of Washington. Rotating magnetic fields were applied using the Los Alamos National Laboratory-built power supply. Standard elongated, flux confined FRCs were generated and sustained in steady state for as long as the power was supplied (up to 2.5 milliseconds). Both analytical and numerical models were developed to explain this unique current drive mechanism, which has many possible applications to fusion confinement.

Facility Operations

FACILITY ACCOMPLISHMENTS

In FY 2001, funding was provided to operate facilities in support of fusion research experiments and to upgrade facilities to enable further research in fusion and plasma science. Examples of accomplishments in this area include:

- The DIII-D program continued to identify improved methods of operation of fusion facilities. DIII-D was operated with high plasma density, a key issue for future machine designs, and the operating methods were extended to the large JET tokamak in England in a collaborative program. Improved performance was achieved in both facilities. Also, DIII-D accomplished a small-scale test of magnetic field feedback controls, which have enabled improved plasma performance. Also, the new Electron Cyclotron Heating System performed very well.
- Improved plasma operating scenarios with long pulses and high reproducibility were developed at NSTX. These efforts include the development of elongation control algorithms, experimentation with plasma current ramp rates, boronization, and between-shots helium glow discharge cleaning. In addition, NSTX plasma operation has been improved by the full coverage of the plasma facing surfaces with carbon tiles, which reduced a significant source of metallic impurities. Further, the neutral beam system was successfully brought into operation.
- The Alcator C-Mod Lower Hybrid heating system improvement project, a combined MIT/PPPL collaboration, successfully completed the system final design, and procurement of components was initiated. The project is on track for completion in FY 2003.
- The TFTR decontamination and decommissioning (D&D) activities at PPPL proceeded on cost and schedule. There were a number of significant technical accomplishments during the year. In the first quarter, PPPL conducted the largest single lift of the project when they removed the 92-ton umbrella structure over the vacuum vessel. In addition, PPPL has filled the TFTR vacuum vessel with concrete and has initiated cutting the vessel into smaller pieces to be sent to a DOE waste repository for burial.

Enabling R&D

SCIENCE ACCOMPLISHMENTS

A number of technological advances were made in FY 2001 that enabled plasma experiments to achieve their research goals, allowed access to experimental regimes in devices not available domestically, and provided innovations in new technologies that improve the vision of fusion as an attractive energy source. Examples include:

- Scientists at Princeton Plasma Physics Lab, University of California San Diego, and Sandia National Lab conducted experiments in a toroidal plasma to investigate the phenomenon of plasma contact with liquid surfaces and to guide development of models for plasma-liquid interactions critical to research on innovative concepts for plasma particle removal and surface heat flux removal. Such capabilities could be readily used for scientific studies in plasma experiments to control key parameters of the plasma edge, such as plasma particle density and temperature, and to carry away intense surface heat locally deposited by the plasma at its edge. For the longer-term, liquid surface technology can provide for much longer lifetimes and higher performance plasma-facing components than is possible with conventional solid surface approaches.

- Researchers at Oak Ridge National Lab, University of California Los Angeles, University of California Santa Barbara, and Lawrence Livermore National Lab developed models for microstructural evolution in candidate fusion materials under simulated conditions associated with fusion. These models unify and integrate the theories on mechanisms that control damage production from energetic neutron bombardment. Also, the models enable nanosystem methods for designing fusion materials with significantly improved performance and lifetimes, and with elemental tailoring that minimizes radioactivity generation by neutron-induced transmutation. The ability to produce superior materials for fusion applications is critical to the viability of using fusion energy for practical applications with benign environmental impacts.
- Researchers at ORNL and PPPL began the design of the prototype of a high power radio frequency antenna that will enable increased levels of plasma heating. The prototype, which will be built in FY 2002 and tested in FY 2003, will validate the design, performance, and fabrication techniques of antennas to be built for use in the JET plasma experiment. These antennas, which will provide the world's most powerful radio frequency plasma heating capability, will permit investigation into advanced modes of fusion-relevant plasma performance.
- Work was initiated on the Safety and Tritium Applied Research (STAR) facility at INEEL, the site for all FES-funded tritium research following the shutdown of the Tritium Systems Test Assembly (TSTA) facility at Los Alamos National Lab. Tritium research at STAR will be focused on more fundamental studies than were conducted at TSTA and will use a small fraction of the tritium used at TSTA for fusion fuel cycle demonstration. In FY 2003, experiments will begin on tritium-related issues of candidate coolant materials for fusion energy systems and of plasma interaction with materials.

AWARDS

- An ORNL researcher received the American Nuclear Society's (ANL) Outstanding Lifetime Achievement Award from the ANS Fusion Energy Division.
- A Cal Tech research scientist has been selected to receive this year's Solar Physics division (SPD) Popular Writing Award to a professional scientist for an article "Simulating Solar Prominences in the Laboratory," which appeared in American Scientist. Each year the SPD Popular Writing Awards Committee awards one prize to a scientist for articles published in U.S. or Canadian newspapers, magazines, or semi-popular journals.
- An NSTX team member at PPPL received the "Engineer of the Year" Award from the New Jersey Society of Professional Engineers, in recognition of outstanding achievements in engineering, contributions to the development of fusion as a long-term energy source, and notable service in enhancing the prestige of the engineering profession.
- The 2001 American Physical Society, Division of Plasma Physics Award for Excellence in Plasma Physics was received by four researchers at three institutions - General Atomics, the University of California, Los Angeles, and the Princeton Plasma Physics Laboratory.
- A University of Maryland fusion theorist received the American Physical Society's James Clark Maxwell Prize for Plasma Physics.

- Eight fusion researchers were elected Fellows of the American Physical Society.
- One fusion researcher was elected a Fellow of the American Nuclear Society.

PROGRAM SHIFTS

The budget requested for FY 2003 is $9,830,000 higher than the FY 2002 Appropriation. The FY 2003 budget generally supports the program balance and priorities recommended by the Fusion Energy Sciences Advisory Committee and supported by the Secretary of Energy Advisory Board and the National Research Council (NRC).

Science

The General Plasma Science program is increased to reflect additional collaborative efforts with NSF. For the remainder of this subprogram, scientific efforts will continue at the pace established in FY 2002.

Facility Operations

Funds made available by the expected completion of the TFTR D&D activity, and an increase of $9.8 million to the overall FES budget are used to increase significantly the run times at each of the three major fusion experimental facilities. The remainder of the funds made available by the completion of the TFTR D&D activity is used to maintain base program research efforts at their FY 2002 level, and to initiate the design and fabrication of the National Compact Stellarator Experiment (NCSX) Major Item of Equipment project at PPPL.

Enabling R&D

Materials research is increased to take advantage of advances in microstructural design of materials for fusion. Funding for Advanced Design and Analysis is reduced nearly $1,000,000 with the completion of a two-year study of possible IFE power plant systems. The remainder of the scientific efforts funded under this subprogram will continue at the pace established in FY 2002.

Workforce Development

The FES program, the Nation's primary sponsor of research in plasma physics and fusion science, supports development of the R&D workforce by funding undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. The R&D workforce developed as a part of this program provides new scientific talent to areas of fundamental research. It also provides talented people to a wide variety of technical and industrial fields that require finely honed thinking and problem solving abilities and computing and technical skills. Scientists trained through association with the FES program are employed in related fields such as plasma processing, space plasma physics, plasma electronics, and accelerator/beam physics as well as in other fields as diverse as biotechnology and investment and finance.

In FY 2001, the FES program supported 365 graduate students and post-doctoral investigators. Of these, 50 conducted research at the DIII-D tokamak at General Atomics, the Alcator C-Mod tokamak at MIT, or the NSTX at PPPL.

Scientific Facilities Utilization

The Fusion Energy Sciences request includes $111,037,000 to operate and make use of major fusion scientific user facilities. The Department's three major fusion energy physics facilities are: the DIII-D tokamak at General Atomics in San Diego, California; the Alcator C-Mod Tokamak at the Massachusetts Institute of Technology; and the National Spherical Torus Experiment at the Princeton Plasma Physics Laboratory. These three facilities are each unique in the world's fusion program and offer opportunities to address specific fusion science issues that will contribute to the expanding knowledge base of fusion. Taken together, these facilities represent a nearly $1,000,000,000 capital investment by the U.S. Government, in current year dollars.

The funding requested will provide research time for about 560 scientists in universities, federally sponsored laboratories, and industry, and will leverage both federally and internationally sponsored research, consistent with a strategy for enhancing the U.S. National science investment.

Funding Profile

(dollars in thousands)

	FY 2001 Comparable Appropriation	FY 2002 Original Appropriation	FY 2002 Adjustments	FY 2002 Comparable Current Appropriation	FY 2003 Request
Fusion Energy Sciences					
Science	131,347	138,252	-592	137,660	142,565
Facility Operations	77,002	74,420	-269	74,151	78,653
Enabling R&D	33,608	35,823	-154	35,669	36,092
Subtotal, Fusion Energy Sciences	241,957	248,495	-1,015	247,480	257,310
General Reduction	0	-1,015	+1,015	0	0
Total, Fusion Energy Sciences	241,957 [a] [b]	247,480	0	247,480	257,310

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

[a] Excludes $5,849,000 which has been transferred to the SBIR program and $351,000 which has been transferred to the STTR program.

[b] Excludes $336,000 transferred to Science Safeguards and Security program in an FY 2001 reprogramming.

Funding By Site

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	7,258	7,378	7,308	-70	-0.9%
Sandia National Laboratories	3,178	2,992	3,213	+221	+7.4%
Total, Albuquerque Operations Office	10,436	10,370	10,521	+151	+1.5%
Chicago Operations Office					
Argonne National Laboratory	2,404	1,661	1,522	-139	-8.4%
Princeton Plasma Physics Laboratory	70,649	68,794	63,576	-5,218	-7.6%
Chicago Operations Office	44,975	44,569	49,317	+4,748	+10.7%
Total, Chicago Operations Office	118,028	115,024	114,415	-609	-0.5%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	2,210	2,326	2,392	+66	+2.8%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	5,510	5,861	5,799	-62	-1.1%
Lawrence Livermore National Laboratory	14,586	14,255	14,411	+156	+1.1%
Oakland Operations Office	71,254	69,004	73,779	+4,775	+6.9%
Total, Oakland Operations Office	91,350	89,120	93,989	+4,869	+5.5%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education	940	419	808	+389	+92.8%
Oak Ridge National Laboratory	17,024	17,884	19,258	+1,374	+7.7%
Oak Ridge Operations Office	39	0	0	0	--
Total, Oak Ridge Operations Office	18,003	18,303	20,066	+1,763	+9.6%
Richland Operations Office					
Pacific Northwest National Laboratory	1,427	1,328	1,556	+228	+17.2%
Richland Operations Office	32	0	0	0	--
Total, Richland Operations Office	1,459	1,328	1,556	+228	+17.2%
Savannah River Operations Office					
Savannah River Laboratory	0	50	49	-1	-2.0%
Washington Headquarters	471	10,959	14,322	+3,363	+30.7%
Total, Fusion Energy Sciences	241,957 [a] [b]	247,480	257,310	+9,830	+4.0%

[a] Excludes $5,849,000 which has been transferred to the SBIR program and $351,000 which has been transferred to the STTR program.

[b] Excludes $336,000 transferred to Science Safeguards and Security program in an FY 2001 reprogramming.

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 enabling R&D program activities. Argonne has a lead role internationally in analytical models and experiments for liquid metal cooling in fusion devices. Studies of coatings for candidate structural alloy materials are conducted in a liquid lithium flow loop. Argonne's capabilities in the engineering design of fusion energy systems have contributed to the design of components, as well as to analysis supporting the studies of fusion power plant concepts.

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 Fusion Energy Sciences program's lead laboratory for fusion safety. As the lead laboratory, it has helped to develop the fusion safety database that will demonstrate the environmental and safety characteristics of both nearer term fusion devices and future fusion power plants. Research at INEEL focuses on the safety aspects of both magnetic and inertial fusion concepts for existing and planned domestic experiments, and developing further our domestic safety database using existing collaborative arrangements to conduct work on international facilities. In addition, with the shutdown of the Tritium Systems Test Assembly (TSTA) facility at LANL, INEEL will expand their research and facilities capabilities to include tritium science activities.

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. For the Fusion Energy Sciences program, the laboratory's mission is to study and apply the physics of heavy ion beams and to advance related technologies for the U.S. Inertial Fusion Energy program. LBNL, LLNL, and PPPL work together in advancing the physics of heavy ion drivers through the Heavy Ion Fusion Virtual National Laboratory.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on an 821-acre site in Livermore, California. LLNL works with the Lawrence Berkley National Laboratory on the Heavy Ion Fusion program. The LLNL program also includes collaborations with General Atomics on the DIII-D tokamak, operation 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. LLNL, LBNL, and PPPL work together in advancing the physics of heavy ion drivers through the Heavy Ion Fusion Virtual National Laboratory.

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 budget supports the creation of computer codes for modeling the stability of plasmas, as well as work in diagnostics, innovative fusion plasma confinement concepts such as Magnetized Target Fusion, and the removal of the remainder of the recoverable tritium in FY 2003 from and completion of the stabilization of the Tritium Systems Test Assembly facility.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE), operated by Oak Ridge Associated Universities (ORAU), is located on a 150-acre site in Oak Ridge, Tennessee. Established in 1946, ORAU is a consortium of 88 colleges and universities. The institute undertakes national and international programs in education, training, health, and the environment. For the FES program, ORISE supports the operation of the Fusion Energy Sciences Advisory Committee and administrative aspects of some FES program peer reviews. It also acts as an independent and unbiased agent to administer the Fusion Energy Sciences Graduate and Postgraduate Fellowship programs, in conjunction with FES, the Oak Ridge Operations Office, participating universities, DOE laboratories, and industries.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000-acre site in Oak Ridge, Tennessee. ORNL develops a broad range of components that are critical for improving the research capability of fusion experiments located at other institutions and that are essential for developing fusion as an environmentally acceptable energy source. The laboratory is a leader in the theory of heating of plasmas by electromagnetic waves, antenna design, and design and modeling of pellet injectors to fuel the plasma and control the density of plasma particles. Research is also done in the area of turbulence and its effect on the transport of heat through plasmas. Computer codes developed at the laboratory are also used to model plasma processing in industry. While some ORNL scientists are located full-time at off-site locations, others carry out their collaborations with short visits to the host institutions, followed by extensive computer communications from ORNL for data analysis and interpretation, and theoretical studies. ORNL is also a leader in stellarator theory and design, and is a major partner with PPPL in conceptual design of the NCSX. ORNL leads the advanced fusion structural materials science program, contributes to research on all materials systems of fusion interest, coordinates experimental collaborations for two U.S.-Japan programs, and coordinates fusion materials activities.

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 research teams and also sends researchers and specialized equipment to other fusion facilities in the United States and abroad. PPPL is the host for the 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 NCSX, a 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 research is focused on developing the scientific understanding and innovations required for an attractive fusion energy source. PPPL scientists are also involved in several basic plasma science experiments, ranging from magnetic reconnection to plasma processing. PPPL, through its association with Princeton University, provides high quality education in fusion-related sciences, having produced more than 175 Ph.D. graduates since it's founding in 1951. PPPL, LBNL, and LLNL work together in advancing the physics of heavy ion drivers through the Heavy Ion Fusion Virtual National Laboratory.

Sandia National Laboratory

Sandia National Laboratory is a Multiprogram Laboratory, located on a 3,700 acre site in Albuquerque, New Mexico, with other sites in Livermore, California, and Tonopah, Nevada. Sandia's Fusion Energy Sciences program plays a lead role in developing components for fusion devices through the study of plasma interactions with materials, the behavior of materials exposed to high heat fluxes, and the interface of plasmas and the walls of fusion devices. Sandia selects, specifies, and develops materials for components exposed to high heat and particles fluxes and conducts extensive analysis of prototypes to qualify components before their use in fusion devices. Materials samples and prototypes are tested in Sandia's Plasma Materials Test Facility, which uses high-power electron beams to simulate the high heat fluxes expected in fusion environments. Materials and components are exposed to tritium-containing plasmas in the Tritium Plasma Experiment. Tested materials are characterized using Sandia's accelerator facilities for ion beam analysis. Sandia supports a wide variety of domestic and international experiments in the areas of tritium inventory removal, materials postmortem analysis, diagnostics development, and component design and testing.

All Other Sites

The Fusion Energy Sciences program funds research at more than 50 colleges and universities located in approximately 30 states. It also funds the DIII-D tokamak experiment and related programs at General Atomics, an industrial firm located in San Diego, California.

Science

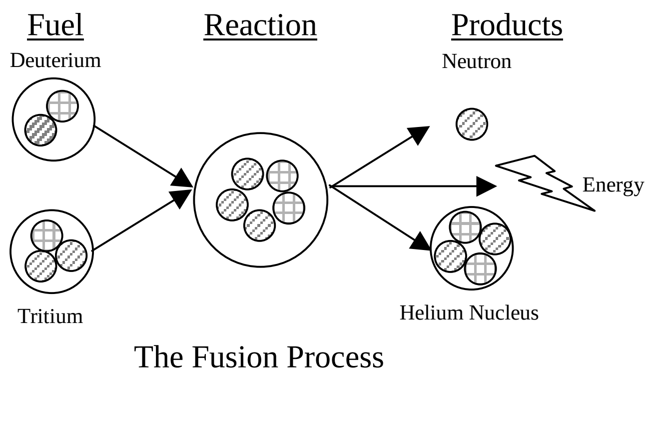
Mission Supporting Goals and Objectives

The Science subprogram develops the basis for a reliable capability to predict the behavior of plasma in a broad range of plasma confinement configurations and use advances in the Tokamak concept to enable the start of the burning plasma physics phase of the U.S. fusion sciences program. Over the next five years FES-funded research will advance the understanding of plasma, the fourth state of matter and enhance predictive capabilities, through comparison of experiments, theory and simulation. This integrated research will focus on well-defined plasma scientific issues including turbulence and transport, macroscopic stability, wave particle interactions and multiphase interfaces. Progress will be made on methods for sustaining and controlling high temperature, high density plasmas, based on improved understanding of fundamental issues. Advanced computational techniques will be integrated into research to provide significantly improved predictive capability for plasma behavior.

An additional objective of the Science subprogram is to broaden the intellectual and institutional base in fundamental plasma science. Two activities, an NSF/DOE partnership in plasma physics and engineering and development grants for junior members of university plasma physics faculties, have been the major contributors to this objective.

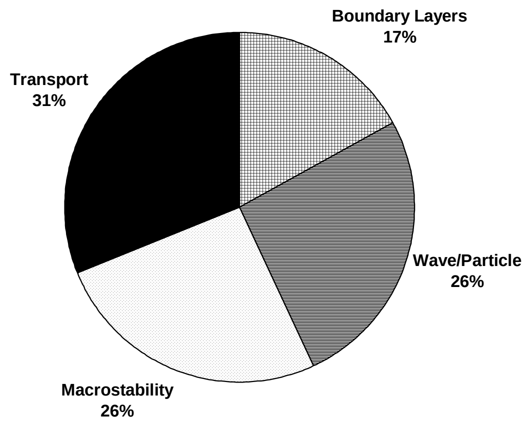
Plasma science is the study of the ionized matter that makes up 99 percent of the visible universe, ranging from neon lights to stars. It includes not only plasma physics but also other physical phenomena in ionized matter, such as atomic, molecular, radiation-transport, excitation and ionization processes. These phenomena can play significant roles in partially ionized media and in the interaction of plasmas with material walls. Plasma science contributes not only to fusion research, but also to many other fields of science and technology, such as astrophysics and industrial processing, and to national security.

Fusion science is focused primarily on describing the fundamental processes taking place in plasmas where the temperatures (greater than 100 million degrees Celsius) and densities permit hydrogenic nuclei that collide to fuse together, releasing energy and producing the nucleus of a helium atom and a neutron.



The Fusion Process

Fusion science shares many scientific issues with plasma science. For Magnetic Fusion Energy (MFE), these scientific issues include: (1) chaos, turbulence, and transport; (2) stability, magnetic reconnection, and dynamos (3) wave-particle interaction and plasma heating; and (4) sheaths and boundary layers. Progress in all of these research issues is likely to be required for ultimate success in achieving a practical fusion energy source.



Science subprogram estimated funding allocation to address the MFE science issues.

For IFE, the two major science issues are: (1) high energy density physics that describes intense laser-plasma and beam-plasma interactions, and (2) non-neutral plasmas, as is seen in the formation, transport, and focusing of intense heavy ion beams.

The largest component of the Science subprogram is research that focuses on gaining a predictive understanding of the behavior of the high temperature, high-density plasmas typically required for fusion energy applications. The tokamak magnetic confinement concept has thus far been the most effective approach for confining plasmas with stellar temperatures within a laboratory environment. Many of the important issues in fusion science are being studied in an integrated program on the two major U.S. tokamak facilities, DIII-D at General Atomics and Alcator C-Mod at the Massachusetts Institute of Technology. Both DIII-D and Alcator C-Mod are operated as national science user facilities with research programs established through public research forums, program advisory committee recommendations, and peer review. There is also a very active program of collaboration with comparable experience abroad aimed at establishing an international database of Tokamak experimental results.

DIII-D has extensive diagnostic instrumentation to measure what is happening in the plasma. It also has unique capabilities to shape the plasma, which, in turn, affect particle transport in the plasma and the stability of the plasma. DIII-D has been a major contributor to the world fusion program over the past decade in the areas of plasma turbulence, energy and particle transport, electron-cyclotron plasma heating and current drive, plasma stability, and boundary layer physics using a “magnetic divertor” to control magnetic field configuration at the edge of the plasma. (The divertor is produced by magnet coils that bend the magnetic field at the edge of the tokamak out into a region where plasma particles following the field are neutralized and pumped away.)

Alcator C-Mod is a unique, compact tokamak facility that uses intense magnetic fields to confine high temperature, high-density plasmas in a small volume. It is also unique in the use of metal (molybdenum) walls to accommodate the high power densities in this compact device. Alcator C-Mod has made significant contributions to the world fusion program in the area of ion-cyclotron frequency wave-particle interaction, plasma heating, stability, and confinement.

In the future, both DIII-D and Alcator C-Mod will focus on using their flexible plasma shaping and dynamic control capabilities to attain good confinement and stability by controlling the distribution of current in the plasma with radio wave current drive and the interface between the plasma edge and the material walls of the confinement vessel with a "magnetic divertor." Achieving these high performance regimes for longer pulse duration will require simultaneous advances in all of the scientific issues listed above.

In addition to the advanced toroidal research on DIII-D and Alcator C-Mod, exploratory work will continue on two university tokamak experiments. The goal of the High Beta Tokamak (HBT) at Columbia University is to demonstrate the feasibility of stabilizing high plasma pressure within a tokamak configuration by a combination of a close-fitting conducting wall, plasma rotation, and active feedback. This work will be closely coordinated with the DIII-D program, and promising results have already been achieved on DIII-D. The Electric Tokamak (ET) at UCLA will explore several new approaches to toroidal magnetic confinement; emphasizing radio wave driven plasma rotation and the achievement of very high plasma pressure relative to the applied magnetic field to produce a deep magnetic well.

The next largest research component is work on alternative concepts, aimed at extending fusion science and identifying concepts that may have favorable stability or transport characteristics that could improve the economic and environmental attractiveness of fusion energy sources. The largest element of the alternative concepts program is the NSTX at Princeton Plasma Physics Laboratory, which began its first full year of operation in FY 2000. Like DIII-D and Alcator C-Mod, NSTX is also operated as a national scientific user facility.

NSTX has a unique, nearly spherical plasma shape that complements the doughnut shaped tokamak and provides a test of the theory of toroidal magnetic confinement as the spherical limit is approached. Its favorable stability properties allow confinement at high plasma pressure relative to the applied magnetic field, and its high rate of shear for the flowing plasma should stabilize turbulence and lead to very good confinement. An associated issue for spherical torus configurations is the challenge of driving plasma current via radio-frequency waves or biasing electrodes. New computational and experimental techniques will be needed for the unique geometry and field configuration of the NSTX.

Exploratory research will also continue, on more than a dozen small-scale, alternative concept devices and basic science experiments, focusing on the scientific topics for which each experiment is optimized. For example, the Madison Symmetric Torus at the University of Wisconsin is a toroidal configuration with high current but low toroidal magnetic field that reverses direction near the edge of the discharge. The magnetic dynamo effect, which results from turbulent processes inside the plasma, spontaneously generates the field reversal at the plasma edge. This innovative experiment is investigating the dynamo mechanism, which is of interest to several fields of science including space and astrophysics, and turbulent transport, which is of interest to fusion science. The Levitated Dipole Experiment, a joint Massachusetts Institute of Technology/Columbia University program is exploring plasma confinement in a novel magnetic dipole configuration (similar to the magnetic fields constraining plasma in the earth's magnetosphere). At the Princeton Plasma Physics Laboratory, the Magnetic Reconnection Experiment addresses fundamental questions in magnetic reconnection, the process by which currents and flows in a plasma can induce changes in the topology of the magnetic field by breaking and reconnecting magnetic field lines. Magnetic reconnection is important not only in fusion experiments but also in phenomena like the solar flares, the solar wind and astrophysical plasmas.

A different set of insights into stability properties of plasmas should be developed from investigations into new stellarator configurations taking advantage of advances in stellarator theory, new computational capabilities, and insights from recent tokamak research. These stellarator configurations are nearly axisymmetric (like a tokamak) but do not require an externally driven current to produce an equilibrium. Thus, they should have transport properties similar to a tokamak but should have different stability properties. A national team is working on the design of a medium-size National Compact Stellarator Experiment (NCSX) that would be used to study plasma turbulence, energy and particle transport, and stability in this novel geometry. Conceptual designs also use an even more radical approach in the Quasi-Poloridal Stellarator (QPS), which has a different symmetry to achieve an even more compact configuration. Both approaches will strengthen U.S. involvement in the much larger world stellarator program.

An entirely different set of science explorations is being carried out in the area of high energy density plasma physics, the underlying field for Inertial Fusion Energy (IFE). In pursuing this science, the 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 NNSA Office of Defense Programs. The IFE program depends on the ICF program for experimental research into the high energy density physics required for the design of energy producing targets and for future testing of the viability of IFE targets in the National Ignition Facility at LLNL. Efforts in IFE focus on understanding the physics of systems that will be needed to produce a viable inertial fusion energy source. These include heavy ion beam systems for heating and compressing a target pellet to fusion conditions, the experimental and theoretical scientific basis for modeling target chamber responses, and the physics of high-gain targets. The physics of intense heavy ion beams and other non-neutral plasmas is both rich and subtle, due to the kinetic and nonlinear nature of the systems and the wide range of spatial and temporal scales involved. For these reasons, heavy ion beam physics is of interest to the larger accelerator and beam physics community. The modeling of the fusion chamber environment is very complex and must include multi-beam, neutralization, stripping, beam and plasma ionization processes, and return current effects.

The theory and modeling program provides the conceptual underpinning for the fusion sciences program. Theory efforts meet the challenge of describing complex non-linear plasma systems at the most fundamental level. These descriptions range from analytic theory to highly sophisticated computer simulation codes, both of which are used to analyze data from current experiments, guide future experiments, design future experimental devices, and assess projections of their performance. Analytic theory and computer codes represent a growing knowledge base that, in the end, is expected to lead to a predictive understanding of how fusion plasmas can be sustained and manipulated.

An important element of the theory and modeling program is the FES portion of the Office of Science's Scientific Discovery Through Advanced Computing (SciDAC) program. Major scientific challenges exist in many areas of plasma and fusion science that can best be addressed through advances in scientific supercomputing. Projects currently underway are focused on understanding and controlling plasma turbulence, investigating the physics of magnetic reconnection, understanding and controlling magnetohydrodynamic instabilities in magnetically confined plasmas, simulating the propagation and absorption of radio waves in magnetically confined plasmas, and understanding atomic physics in the edge region of plasmas.

The general plasma science program supports basic plasma science and engineering research and advances the discipline of plasma physics. Topics explored include a broad range of fundamental research efforts in wave-plasma physics, dusty plasmas, non-neutral plasmas, and boundary layer effects. Important elements of this program include the NSF/DOE Partnership in Basic Plasma Science and Engineering, the Junior Faculty in Plasma Physics Development program, and the basic and applied plasma physics program at DOE laboratories.

In addition to their work on domestic experiments, scientists from the United States participate in leading edge scientific experiments on fusion facilities abroad, and conduct comparative studies to enhance understanding of underlying physics. The Fusion Energy Sciences program has a long-standing policy of seeking collaboration internationally in the pursuit of timely scientific issues. Collaboration avoids duplication of facilities that exist abroad. These include the world's highest performance tokamaks (JET in England and JT-60 in Japan), a stellarator (the Large Helical Device) in Japan, a superconducting tokamak (Tore Supra) in France, and several smaller devices. In addition, the U.S. is collaborating with South Korea on the design of a long-pulse, superconducting, advanced tokamak (KSTAR). These collaborations provide a valuable link with the 80% of the world's fusion research that is conducted outside the U.S.

Finally, development of improved diagnostic tools for analyzing plasma behavior continues to provide new insights into fusion plasmas and enables the detailed comparison between fusion theory and experiments. Non-perturbing measurements of the dynamic temperatures, densities, and electromagnetic fields in the core of near-burning plasmas presents a formidable challenge. Nonetheless, considerable progress in obtaining quantitative measurements has been made over the last decade. Balanced progress in theory and modeling, experimental operation, and the development of improved measurement systems has provided an excellent formula for scientific progress in fusion.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Tokamak Experimental Research	44,960	44,602	48,609	+4,007	+9.0%
Alternative Concept Experimental Research	50,620	50,736	50,913	+177	+0.3%
Theory	27,290	27,146	27,608	+462	+1.7%
General Plasma Science	8,477	8,786	9,060	+274	+3.1%
SBIR/STTR	0	6,390	6,375	-15	-0.2%
Total, Science	131,347	137,660	142,565	+4,905	+3.6%

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Tokamak Experimental Research	**44,960**	**44,602**	**48,609**
▪ **DIII-D Research**	**22,775**	**21,880**	**22,733**

The DIII-D tokamak facility provides the largest, well-diagnosed, high temperature experimental magnetic fusion facility in the U.S. The DIII-D experimental program is structured along the four key Magnetic Fusion Energy (MFE) fusion topical science areas — energy transport, stability, plasma-wave interactions, and boundary physics, and five thrust areas that integrate across topical areas to achieve fusion goals. In FY 2003, funding for physics research and data analysis will be increased. Research in all topical science and thrust areas will be pursued using the new microwave heating hardware modifications, a new diagnostic for current profile measurements, and enhanced computational tools. In particular, emphasis on testing different transport theories by comparison of experimental results and physics based computer models will continue. Control of stability limits, which has gone through an initial phase of experiments, will be further investigated by modification of current profiles with electron cyclotron waves. These studies are closely coupled to the theoretical basis for the instabilities. The installation of equipment that will allow 6 MW of electron cyclotron heating power to be injected into the plasma will be completed in the first quarter of FY 2002; this heating power will be used to further verify the predicted current drive physics. A new DIII-D operating mode exhibits two radial regions of improved heat insulation (transport barriers). The resulting plasmas have very high performance and possible steady state potential. Research efforts will be focused on finding a way to alleviate limitations imposed by the requirement of neutral beam injection in a direction to reduce the plasma current (for shaping the current profile) while maximizing the amount of current generated by the plasma itself. In FY 2003, the experimental operating time is being increased allowing an expanded experimental program on the topical science areas and on investigation of the physics of promising new approaches to Advanced Tokamaks.

▪ **Alcator C-Mod Research**	**7,391**	**7,745**	**8,464**

The Alcator C-Mod facility, by virtue of its very high magnetic field, is particularly well suited to operate in plasma regimes that are relevant to future, much larger fusion tokamaks as well as to compact, high field and density burning plasma physics tokamaks. The approach to ignition and sustained burn of a plasma is an important integrating science topic for fusion. In FY 2003, the funding for physics research and data analysis will be significantly increased from its current level. Research will be pursued to examine the physics of the plasma edge, power and particle exhaust from the plasma, mechanisms of self-generation of flows in the plasma, and the characteristics of the advanced confinement modes that are achieved in the plasma when currents are driven by radio waves. It will also continue to focus on exploring physics techniques for radiating away the large parallel heat flow encountered in the plasma exhaust at high densities and on visualization diagnostics for turbulence in the edge and core of high density plasmas. Increased operation of the machine will also allow further exploration of the compact high field tokamak regimes and operation scenarios required for achievement of ignition in compact devices. A new lower hybrid current drive system will be in the process of being commissioned. In FY 2003, radio frequency heating power will be increased and better discharge density control will be implemented, creating plasma conditions characterized by low collisionality, close to that required for a future power plant.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **International Collaborations and Education**.....................	**7,550**	**8,005**	**10,255**

International collaboration provides the opportunity for U.S. scientists to work with their colleagues on unique foreign tokamaks (JET, Tore Supra, TEXTOR, and ASDEX-UG in Europe, JT-60U in Japan, and KSTAR in Korea). These collaborations produce complementary and comparative data to those obtained on the U.S. tokamaks to further the scientific understanding of fusion physics and enhance the pace of fusion energy development. The United States will participate in the International Tokamak Physics Activity (ITPA) with Japan, Europe, and Russia to enhance collaboration on physics issues related to tokamak burning plasmas. In FY 2003, the collaboration with these programs will focus on ways of using the unique aspects of these facilities to make progress on the four key MFE Science issues cited in the Science Subprogram description. Funding for educational activities in FY 2003 will support research at historically black colleges and universities, graduate and postgraduate fellowships in fusion science and technology, summer internships for undergraduates, general science literacy programs for teachers and students, and outreach efforts related to fusion science and technology.

	FY 2001	FY 2002	FY 2003
▪ **Experimental Plasma Research (Tokamaks)**.....................	**7,244**	**6,972**	**7,157**

Funding provided in this category supports research on innovative tokamak experiments at universities and the development of diagnostic instruments.

Several unique, innovative tokamak experiments are supported. In FY 2003, the High Beta Tokamak at Columbia will continue work on feedback stabilization of magnetohydrodynamic instabilities. Experiments in the Electric Tokamak at UCLA will continue to be directed at developing an understanding of the effects of plasma rotation at progressively higher levels of radio frequency heating power.

Development of unique measurement capabilities (diagnostic systems) that provide an understanding of the plasma behavior in fusion research devices will continue. This research provides the necessary information for analysis codes and theoretical interpretation. Some key areas of diagnostic research include the development of: (1) techniques to measure the cause of heat and particle loss from the core to the edge of magnetically confined plasmas, including techniques aimed at understanding how barriers to heat loss can be formed in plasmas; (2) methods to measure the production, movement, and loss/retention of the particles that are needed to ignite and sustain a burning plasma; and (3) new approaches that are required to measure plasma parameters in alternate magnetic configurations, which add unique constraints due to magnetic field configuration and strength, and limited lines of sight into the plasma. The requested funding level in FY 2003 supports the highest-rated renewal proposals, as well as any new research programs, that are recommended for funding as a result of a competitive peer review of the diagnostics development program in FY 2002.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Alternative Concept Experimental Research	**50,620**	**50,736**	**50,913**
▪ **NSTX Research**	**12,446**	**12,625**	**13,696**

NSTX is the one of the world's two largest embodiments of the spherical torus confinement concept. Plasmas in spherical tori have been predicted to be stable even when high ratios of plasma-to-magnetic pressure and self-driven current fraction exist simultaneously in the presence of a nearby conducting wall bounding the plasma. If these predictions are verified in detail, it would indicate that spherical tori use applied magnetic fields more efficiently than most other magnetic confinement systems and, could therefore, be expected to lead to more cost-effective fusion power systems in the long term.

In FY 2003, the funding for physics research and data analysis will be increased. The NSTX research team will focus on evaluating the plasma stability limits with auxiliary heating. Procedures for operating NSTX while using an improved control system will be refined. The investigation of the spherical torus plasma properties appropriate for enabling plasma pulse durations up to 1 second using non-inductive current drive is a crucial mission element of the NSTX program. The experience and understanding in current startup and maintenance using Coaxial Helicity Injection, radio-frequency wave, pressure gradient (bootstrap current), and magnetic induction will be combined to create the plasma conditions that minimize the dissipation of the solenoid magnet flux while permitting increased plasma pulse durations. In FY 2003 the program will demonstrate the use of a combination of non-inductive techniques to assist in starting up the plasma and sustaining it for up to 1 second and in development of operational scenarios for subsequent requirements of longer duration and higher performance plasmas. Extensive measurements and analysis of the interactions among these current drive techniques will be carried out over a range of plasma parameters and conditions to establish a basis to begin the development of the plasma conditions that enable the extension of the plasma pulse toward 5 seconds during FY 2004-2006.

In preparation for longer-term objectives, the research activities will concentrate on measuring and analyzing the dispersion of edge heat flux and assessing the impact on plasma facing component requirements under high heating power in NSTX; exploring and characterizing spherical torus plasmas having simultaneously good plasma containment and high plasma-to-magnetic pressure ratio for durations much larger than the energy containment times; and measuring and analyzing the effects of energetic ion driven instabilities on the physics mechanisms that limit the high ratios of plasma-to-applied toroidal field pressure and high energy confinement efficiency in spherical torus plasmas. The spherical torus plasma, as in all high beta plasmas, is uniquely characterized by fast ions of supra-Alfven velocities and with large radius of gyration relative to plasma size that could potentially lead to new plasma behaviors of interest. Comparison with theory will contribute to the scientific understanding of these effects needed to consider future experiments with similar energetic ion properties.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Experimental Plasma Research (Alternatives)**..................	**24,536**	**24,609**	**23,443**

This budget category includes most of the experimental research on plasma confinement configurations outside of the three major national facilities described above. Funds in this category are provided for twelve small experiments, one intermediate level proof-of-principle experiment (reversed field pinch), and research in support of a novel compact stellarator design.

The majority of the research is directed toward toroidal configurations (the toroidal direction is the long way around a magnetic "doughnut"). For configurations with a large toroidal magnetic field, the research is focused on stellarators with special combinations of confining magnetic fields. The Helically Symmetric Torus at the University of Wisconsin is the world's first stellarator designed to use a simplified combination of such magnetic fields. Stellarator research at Auburn, ORNL, and PPPL also supports the new proof-of-principle experiment, NCSX, being proposed as part of the facility operation subprogram.

Two small spherical tori, the Helicity Injection Tokamak at the University of Washington and the Pegasus Experiment at the University of Wisconsin, are used in the experimental study of the physics of these compact toroidal shapes. Of particular interest for many of these small-scale experiments are methods used to form the magnetic shapes and to sustain them by injection of additional current in a controlled manner so that the configuration is not de-stabilized and destroyed.

Research on high energy density configurations in which the toroidal field is less than the poloidal (the short way around the magnetic "doughnut") field concentrates on pulse sustainment, confinement, and magnetic field reconnection (formation) processes. Many of these innovative experiments have relatively short pulses in comparison to tokamak discharges, and these experiments are investigating means of sustaining the pulse. These programs include the Madison Symmetric Torus (University of Wisconsin), a spheromak experiment at LLNL, and a small experiment at the California Institute of Technology designed to study the basic physics of the reconnection (formation) process itself.

Research on toroidal systems with the highest energy density includes systems with no toroidal magnetic field and relatively small poloidal magnetic fields. The field reversed configuration (FRC) experiment at the University of Washington, the world's most advanced experiment of this type, focuses on sustaining the relatively short pulses of these plasmas through novel electrical and plasma processes. The ion ring experiment at Cornell University seeks gross stabilization of the FRC through the use of large particle orbits in the magnetic fields (charged particles tend to move in circles in magnetic fields, hence the "orbit"). The levitated dipole experiment (LDX) at MIT will be studying a variant where the confining poloidal magnetic fields are generated by a superconducting magnetic ring located within the plasma itself. Dipole confinement is of great scientific interest in many solar and astrophysical plasma systems.

The magnetized target fusion program (funded by the FES program) at LANL and the Air Force Research Laboratory will study the possibility that an FRC plasma can be compressed to multi-keV temperatures using fast liner compression technology developed by the DOE Defense Programs.

In FY 2003, research efforts on most of these exploratory activities will continue. Research on new concepts will be initiated and old ones discontinued as appropriate through peer review.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Inertial Fusion Energy Experiments**	**13,638**	**13,502**	**13,774**

The inertial fusion energy program has research components that encompass many of the scientific and technical elements that form the basis of an inertial fusion energy system. Heavy ion accelerators continue to be the leading IFE driver candidate. Understanding the physics of the intense heavy ion beam (multiple charged Bismuth, for example), a non-neutral plasma, is one of the outstanding scientific issues. Considerable progress has been made on developing a predictive physics model for intense heavy ion beams. This model, which includes aspects of the accelerator system, has the goal of providing an "end to end" simulation of a heavy ion accelerator. The close interplay between scaled experiments and theory and calculation assures that the model has been validated against experiment. Technical elements of the program include the continuing development of experimental systems to study beam formation by high current ion sources, beam acceleration and focusing. The high current experiment (HCX) at LBNL will be the primary experimental facility for heavy ion beam transport studies. The 500 kV test stand at LLNL will be used to study the physics of intense ion sources. Physics experiments carried out on NNSA-funded facilities including the National Ignition Facility (NIF) will provide high energy density physics data to be used in the design of targets for IFE experiments. NIF will provide validation of target design for actual model targets. The IFE science program will be focused on scientific and technical elements that will allow progress toward future integrated experiments.

Theory	**27,290**	**27,146**	**27,608**

The goal of the theory and computation program is to achieve a quantitative understanding of the behavior of fusion plasmas for interpreting experiments and for guiding the design of future devices. Considerable progress has been made in areas of macroscopic equilibrium and stability of magnetically confined plasmas and turbulence and transport in tokamak plasmas.

The theory and modeling development program is a broad-based program with researchers located at national laboratories, universities, and industry. The main thrust of the work in tokamak theory is aimed at developing a predictive understanding of advanced tokamak operating modes. These tools are also being extended to innovative or alternate confinement geometries. In alternate concept theory, the emphasis is on understanding the fundamental processes determining equilibrium, stability, and confinement in each concept. The generic theory work supports the development of basic plasma theory and atomic physics theory that is applicable to fusion research and to basic plasma science. A separate modeling effort is dedicated to developing computational tools to assist in the analysis of experimental data.

In FY 2003 the theory and computation program will continue to emphasize advanced computing and will make use of rapid developments in computer hardware to attack complex problems involving a large range of scales in time and space. These problems were beyond the capability of computers in the past, but advancements in computation are allowing a new look at problems that once seemed almost intractable. The objective of the advanced computing activities, including the SciDAC program, is to promote the use of modern computer languages and advanced computing techniques to bring about a qualitative improvement in the development of models of plasma behavior. This will ensure that advanced modeling tools are available to support a set of innovative national experiments and fruitful collaboration on major international facilities. In FY 2003, efforts will be focused on comparison of

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

experimental results with improved turbulence calculations, the inclusion of the plasma's self-generated currents in gross stability simulations, simulation of the propagation and absorption of short wavelength waves in magnetized plasmas, and improved simulations of magnetic reconnection. These additions will improve the fidelity of the simulations and provide an enhanced predictive understanding of fusion plasmas.

General Plasma Science	**8,477**	**8,786**	**9,060**

The general plasma science program is directed toward basic plasma science and engineering research. This research strengthens the fundamental underpinnings of the discipline of plasma physics, which makes contributions in many basic and applied physics areas, one of which is fusion energy. Principal investigators at universities, laboratories and private industry carry out the research. A critically important element is the education of plasma physicists. Continuing elements of this program are the NSF/DOE Partnership in Basic Plasma Science and Engineering, the Junior Faculty in Plasma Physics Development program and the basic and applied plasma physics program at DOE laboratories. In FY 2003, the program will continue to fund proposals that have been peer reviewed. A major joint announcement of opportunity in basic plasma physics will be held in 2003 under the NSF/DOE Partnership. Basic plasma physics user facilities will be supported at both universities and laboratories. Atomic and molecular data for fusion will continue to be generated and distributed through openly available databases. The Office of Fusion Energy Sciences will share the cost of funding plasma physics frontier science centers funded by NSF.

SBIR/STTR	**0**	**6,390**	**6,375**

In FY 2001 $4,994,000 and $300,000 were transferred to the SBIR and STTR programs, respectively. The FY 2002 and FY 2003 amounts are the estimated requirements for the continuation of these programs. Beginning in FY 2002, all FES program SBIR/STTR requirements will be funded in the Science subprogram.

Total, Science	**131,347**	**137,660**	**142,565**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Tokamak Experimental Research	
▪ Funding for DIII-D research is increased about 3.9% to provide additional funding for plasma research and data analysis in support of increased facility operations	+853
▪ Funding for Alcator C-Mod research is increased about 9.3% to provide for additional data analysis and research in support of increased facility operations	+719
▪ Funding is increased to allow for funding a number of modest scale research activities pending the outcome of reviews. This also provides partial funding for the transfer of ORNL personnel and equipment to a new experimental site on the ORNL campus	+2,250
▪ The level of funding for Tokamak Experimental Plasma Research is modestly increased to allow scientific efforts at close to the pace established in FY 2002	+185
Total, Tokamak Experimental Research	+4,007
Alternative Concept Experimental Research	
▪ Funding for NSTX research is increased about 8.5% to provide for additional diagnostics development, data analysis, and research in support of increased operations	+1,071
▪ Funding for compact stellarator research at PPPL and ORNL in this subprogram is reduced (-$2,501,000) as funding to start fabrication of the NCSX project is provided under the Facility Operations subprogram. Funding for other Alternate Concepts research is increased (+$1,335,000) to allow scientific efforts to follow up on FY 2002 results	-1,166
▪ Funding for IFE science is slightly increased to allow research to proceed close to the pace established in FY 2002	+272
Total, Alternative Concept Experimental Research	+177
Theory	
▪ Funding for theory and modeling to support experiments is increased to allow scientific efforts to proceed at close to the pace established in FY 2002.	+462
Total, Theory	+462

	FY 2003 vs. FY 2002 ($000)
General Plasma Science	
▪ The funds available for the NSF/DOE partnership are increased to provide funding opportunities within the NSF/DOE partnership, the plasma physics Junior Faculty Development possible program, and support with NSF of plasma science centers..........	+274
Total, General Plasma Science	+274
SBIR/STTR	
▪ Support for SBIR/STTR is provided at the mandated level.	-15
Total Funding Change, Science..	+4,905

Facility Operations

Mission Supporting Goals and Objectives

The Facility Operations subprogram manages all FES facility operations and construction to the highest standards of overall performance, using merit evaluation and independent peer review. The fusion research facilities will be operated in a safe and environmentally sound manner, with high efficiency relative to the planned number of weeks of operation, with maximum quantity and quality of data collection relative to the installed diagnostic capability, and in a manner responsive to the needs of the scientific users. In addition, construction, fabrication and upgrades of major fusion facilities will be accomplished in accordance with highest standards and with minimum deviation from approved cost and schedule baselines.

This activity provides mainly for the operation, maintenance and enhancement of major fusion research facilities; namely, DIII-D at General Atomics, Alcator C-Mod at MIT, and NSTX at PPPL. These user facilities enable U.S. scientists from universities, laboratories, and industry, as well as visiting foreign scientists, to conduct the world-class research funded in the Science and Enabling R&D subprograms. The facilities consist of magnetic plasma confinement devices, plasma heating and current drive systems, diagnostics and instrumentation, experimental areas, computing and computer networking facilities, and other auxiliary systems. The Facility Operations subprogram funds: operating and maintenance personnel, electric power, expendable supplies, replacement parts, system modifications and facility enhancements as well as capital equipment funding for upgrading and enhancing the research capability of DIII-D and C-Mod. In FY2003, a significant increase in the operating time for the major fusion research facilities, to a level of 21 weeks for each facility, is proposed. This will provide an excellent scientific return on the capital investment in these facilities and will enable a much broader investigation of key fusion science issues than heretofore possible. Examples of this scientific return are described in the Science Subprogram section.

With the anticipated completion of TFTR D&D in FY 2002, funding from that activity is proposed to be used in FY 2003 to provide additional support for existing experiments, to increase the operating time of the major facilities and to initiate a Major Item of Equipment project. This project, known as the National Compact Stellarator Experiment (NCSX), would be located at PPPL and consists of the design and fabrication of a compact stellarator proof-of-principle class experiment. The Fusion Energy Sciences Advisory Committee has supported the physics basis for NCSX. This fusion confinement concept has the potential to be operated without plasma disruptions, leading to power plant designs that are simpler and more reliable than those based on the current lead concept, the tokamak. The initial total estimated cost (TEC) of NCSX is $69,000,000, with completion scheduled for mid-FY 2007. However, since the conceptual design has not been completed, the cost and schedule estimates are preliminary.

Funding is also included in this subprogram for General Plant Projects (GPP) and General Purpose Equipment (GPE) at PPPL. GPP and GPE funding supports essential facility renovations and other necessary capital alterations and additions to buildings and utility systems.

In summary, the principal objective of the Facility Operations subprogram is to operate the major fusion research facilities in a safe, environmentally sound manner for the number of weeks shown in the table below. Operating in this manner will maximize the quantity and quality of data collected at the facilities while building a culture of operational excellence and complying with all applicable safety and environmental requirements. Funding included for these facilities provides a significant increase in operating time relative to FY 2002.

The table below summarizes the scheduled weeks of operations for DIII-D, C-Mod, and NSTX.

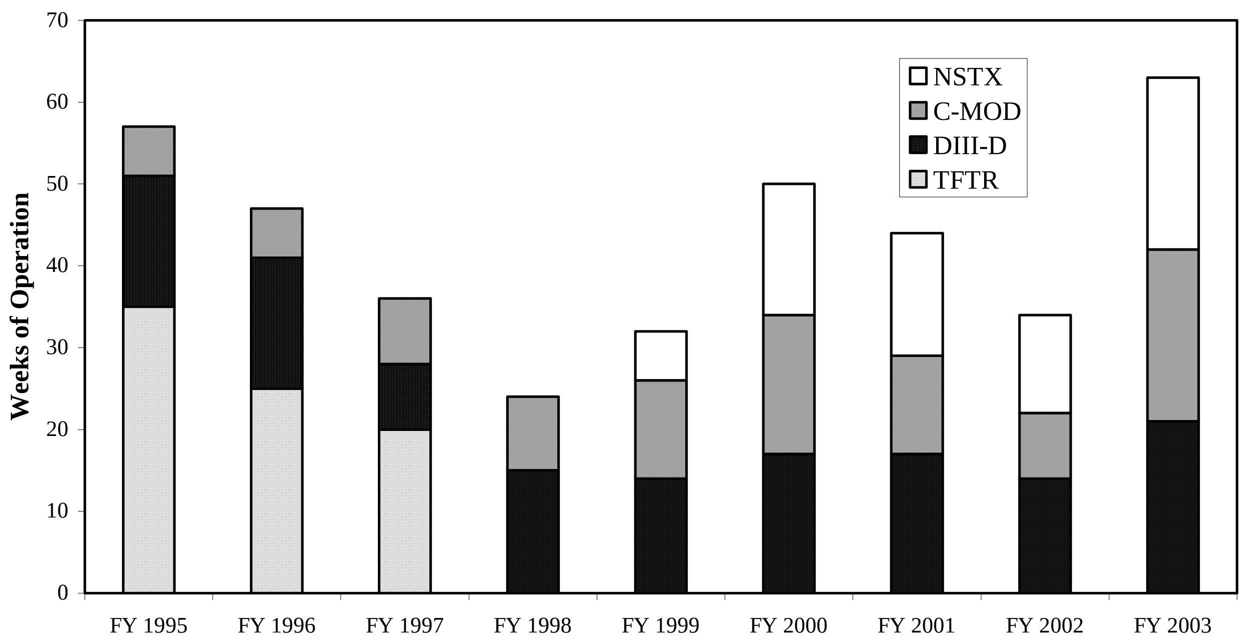
Accomplishments will be reported on specific performance measures involving leadership, excellence, and relevance; quality; and safety and health. The specific measures are for the deviation in weeks of operation of the major facilities to be within 10% of the scheduled weeks and for deviations in cost and schedule for construction, fabrication and upgrade projects to be within 10% of approved baselines. Data on worker injuries will be obtained and reviewed.

Weeks of Fusion Facility Operation

(Weeks of Operations)

	FY 2001	FY 2002	FY 2003
DIII-D	17	14	21
Alcator C-Mod	12	8	21
NSTX	15	12	21

Recent operating history of major fusion experimental facilities



Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
TFTR	19,625	19,604	0	-19,604	--
DIII-D	29,134	29,037	32,909	+3,872	+13.3%
Alcator C-Mod	10,645	9,835	13,789	+3,954	+40.2%
NSTX	15,089	14,186	19,446	+5,260	+37.1%
NCSX	0	0	11,026	+11,026	--
GPP/GPE/Other	2,509	1,489	1,483	-6	-0.4%
Total, Facility Operations	77,002	74,151	78,653	+4,502	+6.1%

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
TFTR	**19,625**	**19,604**	**0**

The TFTR Decontamination and Decommissioning (D&D) activity is planned for completion in FY 2002.

DIII-D	**29,134**	**29,037**	**32,909**

Provide significantly increased support for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems, such as the Electron Cyclotron Heating (ECH) systems. In FY 2003, these funds support 21 weeks of plasma operation.

Alcator C-Mod	**10,645**	**9,835**	**13,789**

Provide significantly increased support for operation, maintenance, major inspection of the electrical generator, and minor machine improvements. In FY 2003, these funds support 21 weeks of plasma operation. Fabrication of a plasma heating and current drive system for Alcator C-Mod will be completed in FY 2003. This enhancement, called lower Hybrid Modification, is a Major Item of Equipment with a TEC of $5,190,000 and a FY 2003 request of $1,019,000.

NSTX	**15,089**	**14, 186**	**19,446**

Provide significantly increased support for operation, maintenance, and improvement of the NSTX facility and installation of planned diagnostic upgrades. In FY 2003, these funds support 21 weeks of plasma operation.

NCSX	**0**	**0**	**11,026**

Initiate a Major Item of Equipment project to design and fabricate a compact stellarator proof-of principle class experiment with a TEC of $69,000,000. The TEC is preliminary because it is based on pre-conceptual design activities. The estimate will be improved as conceptual and preliminary design work is completed. Cost growth of up to 20% may occur before an approved baseline is established.

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		
General Plant Projects/General Purpose Equipment/Other	**2,509**	**1,489**	**1,483**

These funds provide primarily for general infrastructure repairs and upgrades for the PPPL site based upon quantitative analysis of safety requirements, equipment reliability and research needs.

	FY 2001	FY 2002	FY 2003
Total, Facility Operations	**77,002**	**74,151**	**78,653**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
TFTR	
▪ The TFTR Decontamination and Decommissioning (D&D) activity is planned for completion in FY 2002	-19,604
DIII-D	
▪ Experimental operating time is being increased from 14 weeks to 21 weeks to support high priority experiments and thereby relieve a large backlog of desirable research proposals	+3,872
Alcator C-Mod	
▪ Experimental operating time is being increased from 8 weeks to 21 weeks to support high priority experiments that take advantage of C-Mod's unique high field and wave heating systems	+3,954
NSTX	
▪ Experimental operating time is being increased from 12 weeks to 21 weeks to support important experiments that explore the limits of this unique, innovative confinement concept	+5,260
NCSX	
• Funding is provided to initiate the design and fabrication of the NCSX project at PPPL	+11,026
GPP/GPE/Other	
• Funding held essentially constant	-6
Total Funding Change, Facility Operations	+4,502

Enabling R&D

Mission Supporting Goals and Objectives

The Enabling R&D subprogram develops the cutting edge technologies that enable FES research facilities to achieve their goals and investigates innovations needed to create attractive visions of designs and technologies for fusion energy systems.

The Engineering Research element has completed a major restructuring following the U.S. withdrawal from the International Thermonuclear Experimental Reactor (ITER) project. The scope of activities has been substantially broadened to address more fully the diversity of domestic interests in enabling R&D for both magnetic and inertial fusion energy systems. These activities now focus on critical technology needs for enabling U.S. plasma experiments to achieve their full performance capability. Also, international technology collaborations allow the U.S. to access plasma experimental conditions not available domestically. These activities also include investigation of the scientific foundations of innovative technology concepts for future experiments. Another activity is advanced design of the most scientifically challenging systems for next-step fusion research facilities, i.e. facilities that may be needed in the immediate future. Also included are analysis and studies of critical scientific and technological issues, the results of which will provide guidance for optimizing future experimental approaches and for understanding the implications of fusion research on applications to fusion energy.

The Materials Research element continues to focus on the key science issues of materials for practical and environmentally attractive uses in fusion research and facilities while taking steps to implement the FESAC recommendations of 1998 that fusion materials research become more strongly oriented toward modeling and theory activities. This has made this element more effective at using and leveraging the substantial work on nanosystems and computational materials science being funded elsewhere, as well as more capable of contributing to broader materials research in niche areas of materials science. In addition, materials research of interest to both magnetic and inertial fusion energy systems has now been included in this element.

Management of the diverse and distributed collection of fusion enabling R&D activities is being accomplished through a Virtual Laboratory for Technology, with community-based coordination and communication of plans, progress, and results.

Funding Schedule

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Engineering Research	26,979	28,528	28,454	-74	-0.3%
Materials Research	6,629	7,141	7,638	+497	+7.0%
Total, Enabling R&D	33,608	35,669	36,092	+423	+1.2%

Detailed Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Engineering Research	**26,979**	**28,528**	**28,454**
▪ **Plasma Technology**	**12,040**	**11,777**	**12,092**

Plasma Technology efforts will be focused on critical needs of domestic plasma experiments and on the scientific foundations of innovative technology concepts for use in future magnetic and inertial fusion experiments. Nearer-term experiment support efforts will be oriented toward plasma facing components and plasma heating and fueling technologies. By early FY 2003, it is planned to complete testing of a prototype radio frequency antenna for the JET, the world's only plasma experiment using the complete set of fusion fuels, which will enable JET to build a powerful plasma heating device workable under rapidly changing plasma parameters. A design assessment for deploying a first-generation liquid metal system that interacts with the plasma to permit direct control of plasma particle densities and temperatures in NSTX or C-Mod will be completed. By the end of FY 2003, it is planned to complete the basic research that will determine the feasibility of deploying new plasma-facing component technology, which is based on flowing liquid surfaces, that could revolutionize the approach to plasma particle density and edge temperature control in plasma experiments. Development will continue to ensure the needed robustness of the current 1.0 million watt microwave generator that will efficiently heat plasmas to temperatures needed to verify computer models; development will also address critical issues on an advanced 1.5 million watt generator. Funds will be provided to continue superconducting magnet research and innovative technology research in the area of plasma-surface interaction sciences that will enable fusion experimental facilities to achieve their major scientific research goals and full performance potential.

▪ **Fusion Technology**	**9,691**	**10,318**	**10,906**

Fusion Technology efforts will be focused on technology innovations and model improvements needed to resolve critical issues faced by both inertial and magnetic fusion concepts. These issues include identifying innovative approaches to fusion reaction chamber design as well as tritium and safety-related aspects of these chambers. In FY 2003, the required tritium inventory reduction and stabilization at TSTA will be completed and transferred to EM. By early FY 2003, it is planned to begin experiments in the newly constructed Safety and Tritium Applied Research (STAR) Facility at INEEL under a cost-sharing collaboration with Japan to resolve key issues of tritium control and chemistry for coolants proposed to be used in fusion energy systems. Technical assessment will be continued for technology issues and approaches for inertial fusion energy concepts in the areas of the high energy density plasma chambers, target fabrication and tracking, and target-chamber interfaces, including studies of safety issues. Funds will continue to be provided for the US/Japan collaboration

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		

on innovative chamber technology research at a level that allows the US to more fully exploit investments made to enable this collaboration in tritium, coolant flow, and heat transfer research facilities.

▪ **Advanced Design**	**5,248**	**6,433**	**5,456**

Funding for this element will focus on design studies of systems for next-step plasma science experiment options. Systems science studies to assess both the research needs underlying achievement of the safety, economics, and environmental characteristics and the prospects of possible inertial and advanced magnetic confinement concept fusion energy systems will be conducted in an iterative fashion with the experimental community.

Materials Research	**6,629**	**7,141**	**7,638**

Materials Research remains a key element of establishing the scientific foundations for safe and environmentally attractive uses of fusion. Through a wide variety of modeling and experiment activities aimed at the science of materials behavior in fusion environments, research on candidate materials for the structural elements of fusion chambers will continue. Priorities for this work are based on the innovative approaches to evaluating materials and improved modeling of materials behavior that were adopted as a result of recommendations from the FESAC review completed in 1998. Research includes materials and conditions relevant to inertial fusion systems as well as magnetic systems. Investigations will be conducted on the limits of strength and toughness of materials based on dislocation propagation and interactions with crystalline matrix obstacles, and the changes to thermal and electrical conductivity in materials based on electron and photon transport and scattering at the atomic level.

SBIR/STTR	**0**	**0**	**0**

In FY 2001 $855,000 and $51,000 were transferred to the SBIR and STTR programs, respectively. Beginning in FY 2002, all SBIR/STTR requirements will be funded in the Science subprogram.

Total, Enabling R&D	**33,608**	**35,669**	**36,092**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Engineering Research	
▪ Funding for plasma technologies is increased to allow scientific efforts to proceed at the pace established in FY 2002.	+315
▪ Funding for TSTA is decreased slightly to $2,953,000 as efforts to clean up the facility prior to turning it over to the Office of Environmental Management for Decontamination and Decommissioning are expected to be coming to completion. Funding for other fusion technologies activities is increased to allow scientific efforts to proceed at the pace established in FY 2002.	+588
▪ Funding is reduced due to the completion of the series of workshops necessary to prepare for the July 2002 community planning activity.	-977
Total, Engineering Research	-74
Materials Research	
▪ Funding for materials research is increased to allow additional peer reviewed scientific efforts to be initiated	+497
Total Funding Change, Enabling R&D	+423

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
General Plant Projects	2,094	1,370	995	-375	-27.4%
Capital Equipment	9,123	4,975	15,774	+10,799	+217.1%
Total, Capital Operating Expenses	11,217	6,345	16,769	+10,424	+164.3%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2001	FY 2002	FY 2003 Request at Target	Accept-ance Date
DIII-D Upgrade	27,203	26,360	843	0	0	FY 2001
Alcator C-Mod LH Modification	5,190	1,133	1,833	1,205	1,019	FY 2003
NCSX	69,000[a]	0	0	0	11,026	FY 2007
Total, Major Items of Equipment		27,493	2,676	1,205	12,045	

[a] TEC based on pre-conceptual design activities. The estimates will be improved as conceptual and preliminary design work is completed. Cost growth of up to 20% may occur.

Safeguards and Security

Program Mission

The mission of the Office of Science (SC) Safeguards and Security program is to ensure appropriate levels of protection against: unauthorized access, theft, diversion, loss of custody or destruction of Department of Energy (DOE) assets and hostile acts that may cause adverse impacts on fundamental science, national security or the health and safety of DOE and contractor employees, the public or the environment. Each site has a tailored protection program as analyzed and defined in each site's Security Plan (SP) or other appropriate plan. SC's Integrated Safeguards and Security Management (ISSM) strategy encompasses a graded approach to safeguards and security. This approach allows each site to design varying degrees of protection commensurate with the risks and consequences described with their site-specific threat scenarios.

The following is a brief description of the type of activities performed:

Protective Forces

The Physical Protection Protective Forces activity provides for security guards or other specialized personnel and equipment training and management needed to effectively carry out the protection tasks during normal and security emergency conditions.

Security Systems

The Physical Security Protective Systems activity provides for equipment to protect vital security interests and government property per the local threat. Equipment and hardware includes fences, barriers, lighting, sensors, entry control devices, etc. This hardware and equipment is generally operated and used to support the protective guard mission as well.

Information Security

The Information Security activity ensures that materials and documents, that may contain sensitive or classified information, are accurately and consistently identified, properly reviewed for content, appropriately marked and protected from unauthorized disclosure, and ultimately destroyed in an appropriate manner.

Cyber Security

The Cyber Security activity ensures that sensitive and classified information that is electronically processed or transmitted is properly identified and protected, and that all electronic systems have an appropriate level of infrastructure reliability and integrity.

Personnel Security

The Personnel Security activity includes security clearance programs, employee security education and visitor control. Employee education and awareness is accomplished through initial and termination briefings, re-orientations, computer based training, special workshops, publications, signs, and posters.

Material Control and Accountability

The Material Control and Accountability activity provides for the control and accountability of special nuclear materials, including training and development for assessing the amounts of material involved in packaged items, process systems and wastes. Additionally, this activity documents that a theft, diversion or operational loss of special nuclear material has not occurred. Also included is on-site and off-site transport of special nuclear materials in accordance with mission, environmental and safety requirements.

Program Management

The Program Management activity includes policy oversight and development and updating of security plans, assessments and approvals to determine if assets are at risk. Also encompassed are contractor management and administration, planning and integration of security activities into facility operations.

Strategic Objective

SC8-6: Ensure efficient SC program management of research and construction projects through a re-engineering effort of SC processes by FY 2003 that will support world class science through systematic improvements in SC's laboratory physical infrastructure, security, and ES&H.

Progress toward accomplishing this Strategic Objective will be measured by Program Strategic Performance Goals, Indicators and Annual Targets, as follows:

Program Strategic Performance Goals

SC8-6A: Performance will be measured by a 95% success rate for preventing unauthorized intrusions into SC Cyber Systems that process sensitive but unclassified information commensurate with risk.

Performance Indicator

Prevent unauthorized cyber intrusions. This will be accomplished by: (1) Reviewing Computer Incident Advisory Capability (CIAC) incident reports for SC sites that process sensitive but unclassified information to establish a current baseline number of unauthorized intrusions into SC Cyber Systems; and (2) 100% of SC CSPPs submitted and approved in a complete and timely manner. (SC8-6A)

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
During FY 2001, no national security incidents occurred within SC that caused unacceptable risk or damage to the Department. [Met Goal]	Establish baseline of actual intrusions.	95% success rate for preventing unauthorized intrusions into SC Cyber Systems that process sensitive but unclassified information commensurate with risk from FY 2002 baseline. This will be accomplished by: (1) Reviewing Computer Incident

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
		Advisory Capability (CIAC) incident reports for SC sites that process sensitive but unclassified information to establish a current baseline number of unauthorized intrusions into SC Cyber Systems; (2) Achieving, maintaining, and verifying that incidents remain below 5% and update Computer Security Program Plans (CSPPs) to reflect this posture; and (3) 100% of SC CSPPs submitted and approved in a complete and timely manner. (SC8-6A)

SC8-6B: Performance will be measured by a 95% success rate for prevention of unauthorized access into SC security areas.

Performance Indicator

Prevent unauthorized physical intrusions. This will be accomplished by: (1) Reviewing SC security area authorizations, central alarm station, and protective force post and patrol discrepancy logs to establish a current baseline number; and (2) 100% of Facility Security Surveys accomplished in a complete and timely manner. (SC8-6B)

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
During FY 2001, no national security incidents occurred within SC that caused unacceptable risk or damage to the Department. [Met Goal]	Establish baseline of actual intrusions.	95% success rate for prevention of unauthorized access into SC Security areas from FY 2002 baseline. This will be accomplished by: (1) Reviewing SC security area authorizations, central alarm station, and protective force post and patrol discrepancy logs to establish a current baseline number; (2) Achieving, maintaining, and verifying that unauthorized access incidents are less than 5%; and (3) 100% of Facility Security Surveys accomplished in a complete and timely manner. (SC8-6B)

Significant Accomplishments and Program Shifts

In FY 2003 there are no significant program shifts. In FY 2002 increased program emphasis was provided to cyber security commensurate with increased threats and technology advances. These improvements are in place and continue to be updated commensurate with technology advances and program risks. Physical security upgrades will be completed to ensure the protection of special nuclear materials as well as technical enhancements to electronic access controls.

Funding Profile

(dollars in thousands)

	FY 2001 Comparable Appropriation	FY 2002 Original Appropriation	FY 2002 Adjustments	FY 2002 Comparable Current Appropriation	FY 2003 Request
Science Safeguards and Security					
Protective Forces	21,207	25,511	-4,105	21,406	22,345
Security Systems	3,798	7,473	-2,304	5,169	4,532
Information Security	874	1,248	-212	1,036	1,000
Cyber Security	6,631	10,630	-31	10,599	11,714
Personnel Security	1,859	2,837	-144	2,693	2,576
Material Control and Accountability	1,787	3,330	-683	2,647	2,676
Program Management	2,925	4,383	-324	4,059	3,284
Subtotal, Science Safeguards and Security	39,081	55,412	-7,803	47,609	48,127
Less Security Charge for Reimbursable Work	-4,648	-4,912	452	-4,460	-4,383
Subtotal, Science Safeguards and Security	34,433	50,500	-7,351	43,149	43,744
General Reduction	0	-205	205	0	0
Total, Science Safeguards and Security	34,433[ab]	50,295	-7,146	43,149[b]	43,744

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

[a] Includes $5,280,000 transferred from other Science programs ($4,780,000) and NNSA ($500,000) in an FY 2001 reprogramming.

[b] Excludes $6,194,000 in FY 2001 and $7,146,000 in FY 2002 transferred to Environmental Management in FY 2003 for Argonne National Laboratory – West safeguards and security activities.

Funding By Site

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Chicago Operations Office					
Ames Laboratory	264	397	409	+12	+3.0%
Argonne National Laboratory	5,139	7,679	7,809	+130	+1.7%
Brookhaven National Laboratory	9,428	10,916	10,970	+54	+0.5%
Fermi National Accelerator Laboratory	2,430	2,763	2,837	+74	+2.7%
Princeton Plasma Physics Laboratory	1,735	1,828	1,855	+27	+1.5%
Total, Chicago Operations Office	18,996	23,583	23,880	+297	+1.3%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	3,492	4,706	4,753	+47	+1.0%
Stanford Linear Accelerator Center	1,814	2,150	2,207	+57	+2.7%
Total, Oakland Operations Office	5,306	6,856	6,960	+104	+1.5%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education	884	1,248	1,254	+6	+0.5%
Oak Ridge National Laboratory	4,939	7,882	7,913	+31	+0.4%
Thomas Jefferson National Accelerator Facility	552	947	972	+25	+2.6%
Oak Ridge Operations Office	8,404	7,062	7,148	+86	+1.2%
Total, Oak Ridge Operations Office	14,779	17,139	17,287	+148	+0.9%
Washington Headquarters	0	31	0	-31	--
Total, Science Safeguards and Security	39,081	47,609	48,127	+518	+1.1%
Less Security Charge for Reimbursable Work	-4,648	-4,460	-4,383	+77	+1.7%
Total, Science Safeguards and Security	34,433[a][b]	43,149[b]	43,744	+595	+1.4%

[a] Includes $5,280,000 transferred from other Science programs ($4,780,000) and NNSA ($500,000) in an FY 2001 reprogramming.

[b] Excludes $6,194,000 in FY 2001 and $7,146,000 in FY 2002 transferred to Environmental Management in FY 2003 for Argonne National Laboratory – West safeguards and security activities.

Site Description

Safeguards and Security activities are conducted to meet the requirements of the following program elements: Physical Protection Protective Forces, Physical Security Protective Systems, Information Security, Cyber Security, Personnel Security, Material Control and Accountability, and Program Management. A summary level description of each activity is provided in the preceding Program Mission narrative. These activities ensure adequate protection of DOE security interests.

The attainment of the Safeguards and Security program goals and objectives are measured by progress made towards established performance measures. The technical excellence of the field security program is continually re-evaluated through field and Headquarters reviews. **Performance will be measured** at all sites by accomplishing the following:

- 95% success rate for preventing unauthorized intrusions into SC Cyber Systems that process sensitive but unclassified information commensurate with risk.
- 95% success rate for prevention of unauthorized access into SC security areas.

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
Ames Laboratory..	**264**	**397**	**409**

The Ames Laboratory Safeguards and Security program coordinates planning, policy, implementation and oversight in the areas of security systems, protective forces, personnel security, material control and accountability, and cyber security. A protective force is maintained to provide protection of personnel, equipment, and property from acts of theft, vandalism, and sabotage through facility walk throughs, monitoring of electronic alarm systems, and emergency communications. Material control and accountability is maintained to prevent and/or deter the loss or misuse of nuclear materials. An increase in cyber security (+$13,000) will assist with current computer infrastructure protection needs and maintain status quo without enhancements. Minor adjustments are made in other elements (-$1,000) because of changing safeguards and security needs. Reimbursable work is included in the numbers above; the amount for FY 2003 is $26,000.

	FY 2001	FY 2002	FY 2003
Argonne National Laboratory...	**5,139**	**7,679**	**7,809**

The Argonne National Laboratory Safeguards and Security program provides protection of nuclear materials, classified matter, government property, and other vital assets from unauthorized access, theft, diversion, sabotage, espionage, and other hostile acts that may cause risks to national security, the health and safety of DOE and contractor employees, the public, or the environment. Program activities include security systems, material control and accountability, information and cyber security, and personnel security. In addition, a protective force is maintained. These activities ensure that the facility, personnel, and assets remain safe from potential threats. An increase (+$108,000) provides continuation of current cyber security initiatives, assist with current computer infrastructure protection needs and (+$94,000) in protective forces. There are adjustments to other elements (-$72,000) because of changing safeguards and security needs. Reimbursable work is included in the numbers above; the amount for FY 2003 is $388,000.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Brookhaven National Laboratory....................................	**9,428**	**10,916**	**10,970**

Brookhaven National Laboratory (BNL) Safeguards and Security program activities are focused on protective forces, cyber security, physical security, and material control and accountability. BNL operates a transportation division to move special nuclear materials around the site. Material control and accountability efforts focus on accurately accounting for and protecting the sites special nuclear materials. An increase (+$150,000) provides continuation of current cyber security initiatives, assist with current computer infrastructure protection needs and (+$312,000) in protective forces. There are adjustments (-$408,000) primarily to security systems and program management because of changing safeguards and security needs. Reimbursable work is included in the numbers above; the amount for FY 2003 is $806,000.

Fermi National Accelerator Laboratory	**2,430**	**2,763**	**2,837**

Fermi National Accelerator Laboratory Safeguards and Security program efforts are directed at maintaining protective force staffing and operations to protect personnel and the facility as well as at continuing cyber security, security systems, and a material control and accountability program to accurately account for and protect the facilities special nuclear materials. An increase to cyber security (+$77,000) will address infrastructure protection needs. There are adjustments to other elements (-$3,000) because of changing safeguards and security needs.

Lawrence Berkeley National Laboratory	**3,492**	**4,706**	**4,753**

The Lawrence Berkeley National Laboratory Safeguards and Security program provides physical protection of personnel and laboratory facilities. This is accomplished with protective forces, security systems, cyber security, personnel security, and material control and accountability of special nuclear material. An increase (+$463,000) provides continuation of current cyber security initiatives, assists with current computer infrastructure protection needs. Protective Forces increases (+$270,000). There is a reduction (-$686,000) to the other elements because of changing safeguards and security needs. Reimbursable work is included in the numbers above; the amount for FY 2003 is $830,000.

Oak Ridge Institute for Science and Education	**884**	**1,248**	**1,254**

The Oak Ridge Institute for Science and Education (ORISE) Safeguards and Security program provides physical protection/protective force services by employing unarmed security officers. The facilities are designated as property protection areas for the purpose of protecting government owned assets. In addition to the government owned facilities and personal property, ORISE possesses small quantities of nuclear materials that must be protected. The program includes information security, personnel security, protective forces, security systems, and cyber security. An increase (+$102,000) provides continuation of current cyber security initiatives, and assists with current computer infrastructure protection needs. Protective forces increases (+$50,000). There are reductions (-$146,000) primarily in security systems and program management because of changing safeguards and security needs. Reimbursable work is included in the numbers above; the amount for FY 2003 is $319,000.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Oak Ridge National Laboratory	**4,939**	**7,882**	**7,913**

The Oak Ridge National Laboratory (ORNL) Safeguards and Security program includes security systems, information security, cyber security, personnel security, material control and accountability, and program management. Program planning functions at the Laboratory provide for short and long range strategic planning, and special safeguards plans associated with both day-to-day protection of site-wide security interests and preparation for contingency operations. Additionally, ORNL is responsible for provision of overall laboratory policy direction and oversight in the security arena, for conducting recurring programmatic self-assessments; for assuring a viable ORNL Foreign Ownership, Control or Influence (FOCI) program is in place; and for identifying, or tracking, and obtaining closure on findings or deficiencies noted during inspections, surveys, or assessments of safeguards and security programs. The increase in cyber security (+$140,000) to assist with current computer infrastructure protection needs is partially offset by a reduction (-$109,000) in program management. Reimbursable work is included in the numbers above; the amount for FY 2003 is $1,945,000.

Oak Ridge Operations Office	**8,404**	**7,062**	**7,148**

The Oak Ridge Operations Office Safeguards and Security program provides for contractor protective forces for the Oak Ridge National Laboratory. This includes protection of a category 1 Special Nuclear Material Facility. The program also consists of a minimal amount of funding for security systems, information security and personnel security. An increase (+$86,000) for protective forces is provided in order to protect people and property.

Princeton Plasma Physics Laboratory	**1,735**	**1,828**	**1,855**

The Princeton Plasma Physics Laboratory Safeguards and Security program provides for protection of nuclear materials, government property, and other vital assets from unauthorized access, theft, diversion, sabotage, or other hostile acts. These activities result in reduced risk to national security and the health and safety of DOE and contractor employees, the public, and the environment. There is a slight increase in the costs of cyber security (+$26,000) and security systems (+$45,000) partially offset by a reduction in program management (-$46,000). Also, there is a minor increase for protective forces (+$2,000). Reimbursable work is included in the numbers above; the amount for FY 2003 is $54,000.

Stanford Linear Accelerator Center	**1,814**	**2,150**	**2,207**

The Stanford Linear Accelerator Center Safeguards and Security program focuses on reducing the risk to DOE national facilities and assets. The program consists primarily of physical protection protective forces and cyber security program elements. An increase (+$49,000) for protective forces is provided to protect people and property, and (+$8,000) for cyber security to assist with current computer infrastructure protection needs. Reimbursable work is included in the numbers above; the amount for FY 2003 is $15,000.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Thomas Jefferson National Accelerator Facility	**552**	**947**	**972**

Thomas Jefferson National Accelerator Facility has a guard force that provides 24-hour services for the accelerator site and after-hours property protection security for the entire site. Other security programs include cyber security, program management, and security systems. An increase (+$28,000) provides continuation of current cyber security initiatives, assist with current computer infrastructure protection needs and (+$19,000) in protective forces. There is an adjustment (-$22,000) primarily in program management because of changing safeguards and security needs.

All Other..	**0**	**31**	**0**

This funding provides for program management needs for the Office of Science in FY 2002.

Subtotal, Science Safeguards and Security.....................	**39,081**	**47,609**	**48,127**
Less Security Charge for Reimbursable Work..............	**-4,648**	**-4,460**	**-4,383**
Total, Science Safeguards and Security...........................	**34,433**	**43,149**	**43,744**

Detailed Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Ames Laboratory					
Protective Forces	126	140	143	+3	+2.1%
Security Systems	30	26	24	-2	-7.7%
Cyber Security	25	135	148	+13	+9.6%
Personnel Security	36	42	42	0	0.0%
Material Control and Accountability	6	6	7	+1	+16.7%
Program Management	41	48	45	-3	-6.3%
Total, Ames Laboratory	264	397	409	+12	+3.0%
Argonne National Laboratory					
Protective Forces	2,255	3,115	3,209	+94	+3.0%
Security Systems	294	480	455	-25	-5.2%
Information Security	126	246	211	-35	-14.2%
Cyber Security	893	1,780	1,888	+108	+6.1%
Personnel Security	634	885	904	+19	+2.1%
Material Control and Accountability	550	780	796	+16	+2.1%
Program Management	387	393	346	-47	-12.0%
Total, Argonne National Laboratory	5,139	7,679	7,809	+130	+1.7%
Brookhaven National Laboratory					
Protective Forces	5,553	5,834	6,146	+312	+5.3%
Security Systems	667	734	577	-157	-21.4%
Information Security	72	126	131	+5	+4.0%
Cyber Security	1,479	2,320	2,470	+150	+6.5%
Personnel Security	43	49	49	0	0.0%
Material Control and Accountability	592	701	742	+41	+5.8%
Program Management	1,022	1,152	855	-297	-25.8%
Total, Brookhaven National Laboratory	9,428	10,916	10,970	+54	+0.5%
Fermi National Accelerator Laboratory					
Protective Forces	1,427	1,646	1,700	+54	+3.3%
Security Systems	388	267	246	-21	-7.9%
Cyber Security	445	703	780	+77	+11.0%
Material Control and Accountability	65	36	49	+13	+36.1%
Program Management	105	111	62	-49	-44.1%
Total, Fermi National Accelerator Laboratory	2,430	2,763	2,837	+74	+2.7%

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Lawrence Berkeley National Laboratory					
Protective Forces	1,086	1,122	1,392	+270	+24.1%
Security Systems	686	1,360	942	-418	-30.7%
Cyber Security	1,336	1,556	2,019	+463	+29.8%
Personnel Security	8	147	11	-136	-92.5%
Material Control and Accountability	16	80	38	-42	-52.5%
Program Management	360	441	351	-90	-20.4%
Total, Lawrence Berkeley National Laboratory	3,492	4,706	4,753	+47	+1.0%
Oak Ridge Institute for Science and Education					
Protective Forces	212	238	288	+50	+21.0%
Security Systems	65	162	100	-62	-38.3%
Information Security	91	145	139	-6	-4.1%
Cyber Security	371	318	420	+102	+32.1%
Personnel Security	140	108	108	0	0.0%
Program Management	5	277	199	-78	-28.2%
Total, Oak Ridge Institute for Science and Education	884	1,248	1,254	+6	+0.5%
Oak Ridge National Laboratory					
Security Systems	1,504	1,790	1,790	0	0.0%
Information Security	203	304	304	0	0.0%
Cyber Security	997	2,165	2,305	+140	+6.5%
Personnel Security	756	1,182	1,182	0	0.0%
Material Control and Accountability	558	1,044	1,044	0	0.0%
Program Management	921	1,397	1,288	-109	-7.8%
Total, Oak Ridge National Laboratory	4,939	7,882	7,913	+31	+0.4%
Oak Ridge Operations Office					
Protective Forces	7,679	6,455	6,541	+86	+1.3%
Security Systems	101	112	112	0	0.0%
Information Security	382	215	215	0	0.0%
Personnel Security	242	280	280	0	0.0%
Total, Oak Ridge Operations Office	8,404	7,062	7,148	+86	+1.2%
Princeton Plasma Physics Laboratory					
Protective Forces	933	903	905	+2	+0.2%
Security Systems	30	68	113	+45	+66.2%
Cyber Security	688	749	775	+26	+3.5%
Program Management	84	108	62	-46	-42.6%
Total, Princeton Plasma Physics Laboratory	1,735	1,828	1,855	+27	+1.5%

	FY 2001	FY 2002	FY 2003	$ Change	% Change
	(dollars in thousands)				
Stanford Linear Accelerator Center					
Protective Forces	1,492	1,557	1,606	+49	+3.1%
Cyber Security	322	593	601	+8	+1.3%
Total, Stanford Linear Accelerator Center	1,814	2,150	2,207	+57	+2.7%
Thomas Jefferson National Accelerator Facility					
Protective Forces	444	396	415	+19	+4.8%
Security Systems	33	170	173	+3	+1.8%
Cyber Security	75	280	308	+28	+10.0%
Program Management	0	101	76	-25	-24.8%
Total, Thomas Jefferson National Accelerator Facility	552	947	972	+25	+2.6%
All Other					
Program Management	0	31	0	-31	--
Subtotal, Science Safeguards and Security	39,081	47,609	48,127	+518	+1.1%
Less Security Charge for Reimbursable Work	-4,648	-4,460	-4,383	+77	+1.7%
Total, Science Safeguards and Security	34,433	43,149	43,744	+595	+1.4%

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Ames Laboratory	
▪ Slight increase in cyber security (+$13,000), and other minor adjustments (-$1,000) because of changing safeguards and security needs..	+12
Argonne National Laboratory	
▪ Increases primarily in protective forces (+$94,000) and cyber security (+$108,000) and other adjustments made (-$72,000) because of changing safeguards and security needs..	+130
Brookhaven National Laboratory	
▪ Increases primarily in protective forces (+$312,000) and cyber security (+$150,000), and other adjustments (-$408,000) primarily in security systems and program management because of changing safeguards and security needs	+54
Fermi National Accelerator Laboratory	
▪ Increase primarily in cyber security (+$77,000) and adjustments to other elements (-$3,000) because of changing safeguards and security needs.	+74
Lawrence Berkeley National Laboratory	
▪ Increases in protective forces (+$270,000) and cyber security (+$463,000) offset by reductions to other elements (-$686,000) because of changing safeguards and security needs.	+47
Oak Ridge Institute for Science and Education	
▪ Increases to protective forces (+$50,000) and cyber security (+$102,000) partially offset by reductions (-$146,000) primarily to security systems and program management because of changing safeguards and security needs	+6
Oak Ridge National Laboratory	
▪ Increase in cyber security (+$140,000) partially offset by a reduction to program management (-$109,000) because of changing safeguards and security needs.	+31
Oak Ridge Operations Office	
▪ Increase in protective forces because of changing safeguards and security needs	+86
Princeton Plasma Physics Laboratory	
▪ Increases primarily in security systems (+$45,000) and cyber security (+$26,000) and other adjustments (-$44,000) primarily in program management because of changing safeguards and security needs...	+27

	FY 2003 vs. FY 2002 ($000)
Stanford Linear Accelerator Center	
▪ Increases in protective forces (+$49,000), and cyber security (+$8,000) because of changing safeguards and security needs	+57
Thomas Jefferson National Accelerator Facility	
▪ Increases primarily in protective forces (+$19,000) and cyber security (+$28,000) and other adjustments (-$22,000) primarily in program management because of changing safeguards and security needs.	+25
All Other	
▪ Reduction in program management for an FY 2002 activity	-31
Subtotal Funding Change, Science Safeguards and Security	+518
Less Security Charge for Reimbursable Work	+77
Total Funding Change, Science Safeguards and Security	+595

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Capital Equipment......................................	161	0	0	0	0.0%
Total, Capital Operating Expenses...............	161	0	0	0	0.0%

Science Program Direction

Program Mission

The mission of Science Program Direction is: to provide and support a skilled, highly motivated Federal workforce to manage a broad set of scientific disciplines, programs, projects, and facilities. This program enables a skilled, highly motivated Federal workforce to manage the Office of Science's (SC) research portfolio and facilities in support of new and improved energy, environmental, and health technologies, and provides continuous science education opportunities.

Science Program Direction consists of three subprograms: Program Direction, Science Education, and Field Operations. Beginning in FY 2003, Program Direction and Field Operations are realigned to include all functions performed in the Office of Science (SC) Field complex in the Field Operations subprogram. With this change, the Program Direction subprogram becomes the single funding source for the SC Federal staff in Headquarters responsible for directing, administering, and supporting the broad spectrum of SC scientific disciplines. The Science Education subprogram supports four educational human resource development programs. The Department is committed to programs that train students to enter careers in Science, Mathematics, Engineering, and Technology (SMET). Each of the development activities within the Science Education subprogram targets a different group to attract a broad range of students and faculty to the programs and to expand the pipeline of students who can enter the SMET workforce. In this fashion the activities should help our national laboratories and the nation meet the demand for a well-trained scientific/technical workforce and strengthen the national security. The Field Operations subprogram is the centralized funding source for the Field Federal workforce responsible for the management and administrative functions at the Chicago and Oak Ridge Operations Offices and program management oversight provided by the site offices supporting SC laboratories and facilities, e.g., Argonne, Brookhaven, Fermi, and Lawrence Berkeley National Laboratories; the Princeton Plasma Physics Laboratory; the Thomas Jefferson National Accelerator Facility; the Stanford Linear Accelerator Center; and the Spallation Neutron Source.

Strategic Objective

SC-8: Ensure efficient SC program management of research and construction projects through a re-engineering effort by FY 2003 that will support world class science through systematic improvements in SC's laboratory physical infrastructure, security, and ES&H.

Progress toward accomplishing these Strategic Objectives will be measured by Program Strategic Performance Goals, Indicators and Annual Targets, as follows:

Program Strategic Performance Goals

SC8-3: Provide and support a world class Federal workforce with the capability to manage basic and applied research and development in support of new and improved energy, environmental, and health technologies by focusing on human capital management, strategic management systems, e-commerce initiatives, and providing efficient information management products and services. (Program Direction subprogram)

Performance Indicators

Number of completed workforce actions; research proposals received electronically.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Establish and fill 10 Excepted Service (EJ) positions. Implement process improvements and automated recruitment methods to expedite filling critical vacancies. [Met Goal]	Prepare a 5-Year Workforce Restructuring Plan. Recruit for all scientific and technical positions via the automated DOE Job On-line to reach a more diverse candidate pool and decrease the time to fill positions. Implement simplified position classification process/system to reduce administrative burdens and processing times. (SC8-3)	Implement actions netting near-term results as identified in 5-Year Workforce Plan. Initiate actions netting long-term culture and process changes. (SC8-3)
Implement the Procurement Module of the SC integrated system for internal grants administration processing. [Met Goal]	Initiate receipt of research proposals electronically through the Procurement Module of the SC integrated system; establish benchmark at 25% - currently at zero. (SC8-3)	Initiate receipt of research proposals electronically through the Procurement Module of the SC integrated system; establish benchmark at 50%. (SC8-3)
Develop and implement corporate application “Execution Work Management” supporting e-receipt/distribution of proposals. 100% roll out of Windows 2000. [Met Goal]	Initiate 2 major enhancements to the corporate application “Execution Work Management” package to include organization and tracking of electronic grants, proposals and abstracts. Implement Intranet Portal to provide a single login to all SC HQ corporate applications; establish benchmark of 100% - currently zero. Implement 2 corporate applications; “Worksheet Exchange” capability to export/import data from the Financial Management Information System for use in budget formulation and “Abstract Tracking” capability to create, modify, manage, view, and publish SC’s project abstracts. (SC8-3)	Implement 2 additional functionalities within the “Support Services” administrative functions package supporting SC’s concurrence process and procedures. Provide 10 new functionalities within the “Intranet” and “Execution Work Management,” packages to include electronic concurrence routing, mechanisms to release and receive field work proposals, etc. (SC8-3)

SC8-4: Expand the number and diversity of the applicant pool in the Office of Science undergraduate research internship programs; establish outside evaluation to assess the quality or the program as measured by student deliverables and evaluations; and develop a tracking system to monitor the long-term impact on career choices. (Science Education subprogram)

Performance Indicator

Number and quality of applicants.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
More than 1,000 applicants for undergraduate laboratory research internships were received. 479 students were selected for summer 2001. 479 students were placed. [Met Goal]	Increase the number and/or diversity of the applicants by 20%. (SC8-4)	Increase the number and/or diversity of the applicants by 10%. (SC8-4)
80% of the student's research abstracts were acceptable for printing in the Undergraduate Research Journal. 15 full research papers are being published along with about 450 abstracts. [Met Goal]	90% of students submit acceptable abstracts. (SC8-4)	90% of students submit acceptable abstracts. (SC8-4)
Begin tracking employment of Participants at National labs and associated institutions. The Center for Workforce Development has begun the tracking of the students that are placed as interns. The database has been created at PNNL and all applicant students have been compiled and waiting for acceptance. After acceptance, the placed students will be tracked. [Met Goal}	Track career choices of at least 25% of the participating students. (SC8-4)	Track career choices of at least 25% of the participating students. (SC8-4)

SC8-5: Support a world class Federal workforce within the SC Field structure that (1) takes federal program and project management actions, (e.g., approvals, permits, self assessments, budgeting, etc.) to ensure safe, secure and efficient mission accomplishment in the field; (2) manages cradle to grave acquisition processes from strategy development to solicitation and award through closeout; (3) takes actions to preserve and protect DOE resources, provide for security of people, property and information, and conduct stakeholder interactions; and (4) maintains internal operations such as human resources, training, payroll and travel, legal counsel and information management, that enable the workforce to successfully perform. (Field Operations subprogram)

Performance Indicator

Percent costs avoided; number of accidents and incidents per year.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
	Take actions appropriate to the Headquarters and Field organizations to reduce SC's cost of doing business. Through re-engineering, areas of improvement will be identified where work could be taken out of the system by process improvements or the elimination of unnecessary requirements, thereby lowering the cost of doing business and improving SC's performance and accountability. These actions will result in Federal staffing changes. (SC8-5)	Continue to take actions appropriate to Headquarters and Field organizations to reduce SC's cost of doing business. Through re-engineering, areas of improvement will be identified where work could be taken out of the system by process improvements or the elimination of unnecessary requirements, thereby lowering the cost of doing business and improving SC's performance and accountability. These actions will result in Federal staffing changes. (SC8-5)
	Using the standard DOE metrics to track security incidents and trends and safety and health performance, take contractual and federal actions to reduce incidents and accidents by at least 20% compared to last year with the goal of zero security infractions and zero accidents. (SC8-5)	Using the standard DOE metrics to track security incidents and trends and safety and health performance, take contractual and federal actions to reduce incidents and accidents by at least 20% compared to last year with the goal of zero security infractions and zero accidents. (SC8-5)

Significant Accomplishments and Program Shifts

SCIENCE ACCOMPLISHMENTS

Program Direction

- Achieved technical excellence in SC programs despite managing one of the largest, most diversified, and complex basic research portfolios in the Federal Government with a relatively small Federal and contractor support staff.
- Aligned Federal safeguards and security activities at Oak Ridge Operations Office under Program Direction commencing in FY 2002.
- In FY 2001, established a partnership with the Office of Management, Budget and Evaluation that resulted in expediting the position classification and recruitment processes.

Science Education

- The Energy Research Undergraduate Laboratory Fellowship (ERULF) program has implemented an innovative, interactive Internet system to receive and process hundreds of student applications for summer, fall, and spring semester research appointments at 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. The on-line application system is linked with an SC laboratory central processing center called EducationLink.

This system will enhance communication with the participants regarding their internships, contain pre- and post-surveys that quantify student knowledge, performance and improvement, and allow SC to measure program effectiveness and track students in their career path, and be a hosting site for publishing student papers and abstracts.

- Through special recruitment efforts, the Energy Research Undergraduate Laboratory Fellowship Program has attracted a diverse group of students using the electronic application. Nearly 20 percent of those submitting applications were from under-represented groups. Approximately 40 percent of the applicants were females, and more than 25 percent were from low-income families. In the summer of 1999, more than 400 appointments were made through the new application process and in the summers of 2000 and 2001 more than 500 appointments were made each year through the new application process.
- An undergraduate student journal was recently created which publishes full-length peer-reviewed research papers and abstracts of students in the program.
- Program Guidebooks were developed for the student participants in ERULF and the Community College Initiative (CCI) which provided formats and instructions for the written requirements, including scientific abstract, research paper, oral presentation, poster and education module.
- One additional regional competition was held in conjunction with DOE's National Science Bowl®. More than 11,000 high school students participated in the 61 regional science bowl tournaments.
- Saturday morning science seminars were added to the National Science Bowl weekend, introducing students to many contemporary issues and findings in scientific research.
- National Science Bowl awards were expanded to include a wide variety of academic awards to the top 18 teams and a Civility Award sponsored by IBM.
- The Albert Einstein Distinguished Educator Fellowship Program placed four outstanding K-12 science, math, and technology teachers in Congressional offices and one at DOE, as directed by legislation. The National Aeronautics and Space Administration and the National Science Foundation contributed funds to place seven additional Einstein Fellows in those agencies.
- In FY 2001, SC piloted for the third year, its DOE Community College Institute of Science and Technology. In the summer of 2001, more than 100 community college students attended a 10-week scientific research experience at several DOE multipurpose laboratories. Almost 60 percent of the participating students came from underrepresented groups in SMET; many were "non-traditional" students.

Field Operations

- Completed Phase I of an electronic-based document system to electronically distribute and track documents and records. Mail handlers now use one common system to log and scan both incoming and outgoing correspondence.
- Successfully implemented the Electronic Commerce–Web Based (EC Web) system. EC-Web is used for simplified acquisition requisitions and credit card purchases.
- Implemented the Employee Self Service (ESS) feature of the Corporate Human Resources Information System (CHRIS). Federal employees can now view payroll, benefits, and other personal information at their desktops via Internet access.

- The Oak Ridge Financial Service Center (ORFSC) successfully completed the migration of financial systems of satellite offices into Oak Ridge; one system now serves all offices: Oak Ridge Operations Office; Office of Scientific and Technical Information; Ohio Field Office; Savannah River Operations Office; Rocky Flats; Richland Operations Office; Strategic Petroleum Reserve Project Office; and the National Energy Technology Laboratory.
- Oak Ridge Operations Office is continuing both the development and the deployment of a budget execution and formulation system that supports funds control, financial plan distribution, and budget formulation. Oak Ridge, Chicago and two other offices, Savannah River and the Strategic Petroleum Reserve, are currently using this web-based system. The system provides a variety of report options used for analysis and funds tracking.
- Two acquisition process improvement activities that affected the closeout process and cost/price analysis at the Chicago Operations Office were conducted. Their implementation resulted in the saving of time and productive labor hours, as well as expediting the closeout process and the award process for Small Business Innovation Research and Small Business Technology Transfer program agreements.
- In response to SC's emphasis on the timely award of assistance instruments, the Chicago Acquisition and Assistance Group established a team to concentrate on processing and administering SC actions. In FY 2000, the team processed 1,149 actions, with an on-time award percentage of 91, which is considered outstanding.
- The Chicago Financial Services Group successfully converted all grants under the Department of Health and Human Services Payment Management System to the Automated Standard Application for Payments (ASAP) during the period May 2000 to February 2001. A schedule is in place to convert all remaining grants to ASAP by March 2002.
- The Chicago Intellectual Property Center of Excellence processed a significant portion of the inventions reported to DOE on innovations made under DOE contracts.
- The Brookhaven Area Office has established the first Small Business Development Center. The center aids small businesses in obtaining financial assistance, and also provides access for small businesses to the scientific staff at the Brookhvaven National Laboratory to help advance technologies for marketing.
- In FY 2001, the Chicago Operations Office incorporated the results of the Information Architecture Plan completed in FY 2000. The plan addresses their business needs and are consistent with Chicago's strategic goals as well as the Clinger-Cohen Act of 1996.
- The Chicago Operations Office successfully supported DOE's science and technology mission at our laboratories through the negotiation and execution of five-year performance-based management and operating contracts. New contracts have been negotiated for Ames Laboratory (December 1999) and Argonne National Laboratory (June 2000). DOE has signed a five-year extension of its contract with Princeton University for management and operation of the Princeton Plasma Physics Laboratory in New Jersey. The new agreement will run from October 1, 2001, to September 30, 2006, and is valued at approximately $350,000,000 based on current funding.
- Initiated action to make the Field Operations subprogram the central funding source for all SC-funded Federal Field activities and take on additional resource requirements beginning in FY 2003, including the transfer of support service activities previously budgeted in the Science Laboratories Infrastructure program (Oak Ridge Landlord activity), and safeguards and security responsibilities at the Chicago Operations Office previously budgeted by the Office of Security and Emergency Operations.

PROGRAM SHIFTS

- Beginning with FY 2003, the Program Direction and Field Operations subprograms are restructured to align all functions performed in the SC Field complex within the Field Operations subprogram. With this change, Program Direction is the funding source for only SC Federal staff in Headquarters. In FY 2003, the Field Operations subprogram becomes the central funding source for all SC sponsored Federal field employees and the cost of administration within the field structure. In addition, support service activity previously budgeted under the Science Laboratories Infrastructure program (Oak Ridge Landlord activity) will be funded under the Field Operations subprogram in FY 2003. Line management responsibility for safeguards and security at both Oak Ridge and Chicago will be funded in the Field Operations subprogram. Funding for Chicago safeguards and security staff is transferred to SC from the Office of Security and Emergency Operations. This approach supports the thrust to reduce overhead by centralizing resources, properly aligning support service and line management responsibilities.
- In addition, SC is in the process of conducting a workforce reengineering study to address fundamental issues and functions within the Office. The study will design ways to maintain or improve SC's performance while reducing the cost of conducting its work. Phase I of the study—underway now—focuses on defining the principles by which a fully integrated Office of Science will operate, and on clarifying roles, responsibilities, authorities and accountabilities across the entire SC organization. Among the principles anticipated to emerge from the study are: use of consensus-based or industry standards rather than agency-specific orders wherever possible, reliance on external performance reviews instead of transactional oversight, tailoring DOE requirements to individual laboratories or programs as appropriate, and creating one seamless Office of Science regardless of geographic location. In anticipation of this, the FY 2003 budget request of $139,479,000 is significantly less than comparable budget requests in prior years. Consistent with the requested dollars, there is a net decrease of 203 full-time equivalents, mostly associated with downsizing the Federal workforce in the Field. The budget request for the Science Education subprogram is $5,460,000.
- The functions within the Environmental Management Science Program previously sponsored by the Office of Environmental Management and associated full-time equivalents (9) are transferred to SC in FY 2003. These resources are included as comparable adjustments in this budget. The Federal staff will become part of the Office of Biological and Environmental Research in Headquarters and thus are funded in the Program Direction subprogram.

Funding Profile

(dollars in thousands)

	FY 2001 Comparable Appropriation	FY 2002 Original Appropriation	FY 2002 Adjustments	FY 2002 Comparable Appropriation	FY 2003 Request
Science Program Direction					
Program Direction	47,831	72,500	-15,494	57,006	58,224
Science Education	4,460	4,460	0	4,460	5,460
Field Operations	87,570	63,000	+28,009	91,009	75,795
Subtotal, Science Program Direction	139,861	139,960	+12,515	152,475	139,479
General Reduction	0	-100	+100	0	0
Total, Science Program Direction	139,861[a b]	139,860	+12,615	152,475[a b]	139,479
Total Excluding Full Funding for Federal Retirements, Science Program Direction	132,865	132,862	+12,615	145,477	133,847
Staffing (FTEs)					
Headquarters (FTEs)	268	284	+9	293	299
Field (FTEs)	0[c]	107[c]	-107	0[c]	0
Field Operations (FTEs)	621	551	+125	676	467
Total, FTEs	889	942	+27	969	766

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

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[a] Excludes $1,050,000 transferred to Science Safeguards and Security program in an FY 2001 reprogramming. Includes $1,100,000 in FY 2001 for transfer of Oak Ridge Landlord safeguards and security responsibility from Science Safeguards and Security program; includes $3,047,000 in FY 2001 and $2,880,000 in FY 2002 transferred from the Science Laboratories Infrastructure program for Oak Ridge Landlord activities; includes $1,533,000 in FY 2001 and $1,598,000 in FY 2002 for Chicago Safeguards and Security staff transferred from the Office of Security and Emergency Operations; and includes $1,329,000 in FY 2001 and $1,139,000 in FY 2002 for the transfer of the Environmental Management Science Program function to SC from the Office of Environmental Management.

[b] The FY 2001 and FY 2002 columns of the FY 2003 Congressional Request include funding in the amount of $6,996,000 and $6,998,000, respectively, for the Government's share of increased costs associated with pension and annuitant health care benefits. These funds are comparable to FY 2003 funding of $5,632,000.

[c] FY 2001 and FY 2002 FTEs are displayed comparable to the FY 2003 Request, where all Field FTEs are budgeted in Field Operations. The FY 2002 original appropriation column displays FTEs noncomparable.

Funding by Site

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Albuquerque Operations Office					
National Renewable Energy Laboratory	0	0	150	+150	--
Chicago Operations Office					
Argonne National Laboratory	430	430	615	+185	+43.0%
Brookhaven National Laboratory	420	430	615	+185	+43.0%
Fermi National Laboratory	50	20	100	+80	+400.0%
Princeton Plasma Physics Laboratory	110	125	100	-25	-20.0%
Chicago Operations Office	35,517	36,025	29,854	-6,171	-17.1%
Total, Chicago Operations Office	36,527	37,030	31,284	-5,746	-15.5%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	40	10	0	-10	--
Idaho Operations Office	35	0	0	0	--
Total, Idaho Operations Office	75	10	0	-10	--
Oakland Operations Office					
Lawrence Berkeley National Laboratory	445	480	750	+270	+56.3%
Stanford Linear Accelerator Center	125	150	150	0	--
Berkeley and Stanford Site Offices	3,279	3,452	3,110	-342	-9.9%
Total, Oakland Operations Office	3,849	4,082	4,010	-72	-1.8%
Oak Ridge Operations Office					
Oak Ridge Institute for Science and Education	714	1,230	1,250	+20	+1.6%
Thomas Jefferson National Accelerator Facility	45	50	100	+50	+100.0%
Oak Ridge Operations Office	49,634	52,067	43,406	-8,661	-16.6%
Total, Oak Ridge Operations Office	50,393	53,347	44,756	-8,591	-16.1%
Richland Operations Office					
Pacific Northwest National Laboratory	185	555	740	+185	+33.3%
Richland Operations Office	764	130	220	+90	+69.2%
Total, Richland Operations Office	949	685	960	+275	+40.1%
Washington Headquarters	48,068	57,321	58,319	+998	+1.7%
Total, Science Program Direction	139,861 [d]	152,475	139,479	-12,996	-8.5%

[d] Excludes $1,050,000 transferred to Science Safeguards and Security program in an FY 2001 reprogramming. Includes $1,100,000 in FY 2001 for transfer of Oak Ridge Landlord safeguards and security responsibility from Science Safeguards and Security program; includes $3,047,000 in FY 2001 and $2,880,000 in FY 2002 transferred from the Science Laboratories Infrastructure program for Oak Ridge Landlord activities; includes $1,533,000 in FY 2001 and $1,598,000 in FY 2002 for Chicago Safeguards and Security staff transferred from the Office of Security and Emergency Operations and includes $1,329,000 in FY 2001 and $1,139,000 in FY 2002 for the transfer of the Environmental Management Science Program function to SC from the Office of Environmental Management.

Site Description

Ames National Laboratory

Ames Laboratory (Ames), located in Ames, Iowa, is an integrated part of Iowa State University. Ames was formally established in 1947, by the Atomic Energy Commission, because of its successful development and efficient process in producing high-purity uranium metal in large quantities for atomic energy. Today, Ames pursues a broad range of priorities in the chemical, materials, engineering, environmental, mathematical and physical sciences. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a multi-program laboratory located on a 1,700-acre site in suburban Chicago. Argonne research falls into 4 broad categories: basic science, scientific facilities, energy resources, and environmental management. ANL has a satellite site located in Idaho Falls, Idaho. This site, referred to as Argonne-West, occupies approximately 900 acres and is the home of most of Argonne's major nuclear reactor research facilities. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Berkeley Site Office

The Berkeley Site Office provides institutional program management oversight in the execution of science programs contracted through Lawrence Berkeley National Laboratory and with US industries and universities.

Brookhaven National Laboratory

Brookhaven National Laboratory is a multi-program laboratory located on a 5,200-acre site in Upton, New York. Brookhaven creates and operates major facilities available to university, industrial, and government personnel for basic and applied research in the physical, biomedical, and environmental sciences, and in selected energy technologies. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Chicago Operations Office

Chicago supports the programmatic missions performed in support of science and technology, national security, energy research, and environmental management. They are responsible for the integrated, performance-based management of five major management and operating (M&O) laboratory sites--Argonne National Laboratory, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Princeton Plasma Physics Laboratory, and Ames Laboratory; and two government-owned and government-operated federal laboratories--Environmental Measurements Laboratory and New

Brunswick Laboratory. Chicago has oversight responsibility for more than 9,500 contractor employees located at various site offices across the Nation. This responsibility includes ensuring the security and safety of the taxpayer’s investment in research facilities and other physical plant worth $4 billion and approximately 16,000 acres of land. Chicago hosts four major DOE Centers of Excellence, and as such, elements throughout the Department rely on Chicago for services and expertise within these areas: Center for Risk Excellence; the Grants Center of Excellence; the Intellectual Property Center of Excellence; and the Center of Excellence in Nuclear Material Measurement Science.

Fermi National Accelerator Laboratory

Fermi National Accelerator Laboratory (Fermilab) is located on a 6,800-acre site in Batavia, Illinois. It is the largest U.S. laboratory for research in high-energy physics and is second only to CERN, the European Laboratory for Particle Physics, in the world. About 2,500 scientific users, scientists from universities and laboratories throughout the U.S. and around the world, use Fermilab for their research. Fermilab's mission is the goal of high-energy physics: to learn what the universe is made of and how it works. Fermilab builds and operates the facilities that high-energy physicists need to do forefront research, and develops new accelerator technology for the experiments of the future. Fermilab is operated by Universities Research Association, a consortium of 89 research universities. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Idaho National Engineering and Environmental Laboratory

The Idaho National Engineering and Environmental Laboratory (INEEL) is located on 890 square miles in the southeastern Idaho desert. Other INEEL research and support facilities are located in nearby Idaho Falls. Within the laboratory complex are nine major applied engineering, interim storage and research and development facilities, operated by Bechtel, B&W Idaho for the U.S. Department of Energy. Today, INEEL is solving critical problems related to the environment, energy production and use, U.S. economic competitiveness, and national security. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a multi-program laboratory located in Berkeley, California, on a 200-acre site adjacent to the Berkeley campus of the University of California. The Laboratory is dedicated to performing leading-edge research in the biological, physical, materials, chemical, energy, and computer sciences. The Laboratory also operates unique user facilities available to qualified investigators. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

National Renewable Energy Laboratory

The National Renewable Energy Laboratory (NREL) is located on a 300-acre campus at the foot of South Table Mountain in Golden, Colorado. It is the world leader in renewable energy technology development. Since its inception in 1977, NREL's sole mission has been to develop renewable energy and energy efficiency technologies and transfer these technologies to the private sector. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on a 150-acre site in Oak Ridge, Tennessee. ORISE conducts research into modeling radiation dosages for novel clinical, diagnostic, and therapeutic procedures. In addition, ORISE coordinates several research fellowship programs and the peer review of all Basic Energy Sciences funded research. ORISE manages and administers ORNL undergraduate research opportunities for students and faculty.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a multi-program laboratory located on a 24,000-acre site in Oak Ridge, Tennessee. Scientists and engineers at ORNL conduct basic and applied research and development to create scientific knowledge and technological solutions that strengthen the nation's leadership in key areas of science; increase the availability of clear, abundant energy; restore and protect the environment; and contribute to national security.

Oak Ridge Operations Office

Oak Ridge is responsible for implementing elements of almost every major Departmental mission in science, energy resources, an environmental quality. They have oversight responsibility for ORNL, Thomas Jefferson National Accelerator Facility, Spallation Neutron Source, East Tennessee Technology Park (ETTP), Paducah Gaseous Diffusion Plant, Portsmouth Gaseous Diffusion Plant, and the Oak Ridge Institute for Science and Education (ORISE). Oak Ridge also supports the recently established Y-12 Area Office under the National Nuclear Security Administration. Oak Ridge has oversight responsibility for more than 15,000 contractor employees located at these sites, as well as responsibility for over 43,000 acres of land and approximately 46,000,000 square feet of facility space, valued at over $12 billion. Other major initiatives at Oak Ridge include the successful transition of Portsmouth to cold standby; equipping facilities needed to support the DOE missions; developing and maintaining a trained, capable workforce; issuing a contract for the Uranium Depleted Uranium Hexafloride (DUF_6) Conversion Center; accelerating cleanup activities at all sites; expanding and maintaining prominence as a resource for advance neutron science; focusing on reindustralization and asset management; revitalizing ORNL; and using the Joint Institute for Biological Sciences and other resources to move ahead to the next phase of human genome research. Oak Ridge is also recognized as one of the Department's three Financial Centers of Excellence.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a multi-program laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The Laboratory conducts research in the area of environmental science and technology and carries out related national security, energy, and human health programs. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

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 primary mission of PPPL is to develop the scientific understanding and the innovations, which will lead to an attractive fusion energy source. Associated missions include conducting world-class research along the broad frontier of plasma science and providing the highest quality of scientific education. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Richland Operations Office

Richland is responsible for and manages all environmental cleanup and science and technology development at the 560 square mile Hanford Site, coordinating closely with contractor companies hired to manage and complete the work of the world's largest cleanup project. The primary contractors are Fluor Daniel Hanford and its subcontractors, the Bechtel Hanford, Inc, the Hanford Environmental Health Foundation, and the Battelle Memorial Institute, which serves as the contractor for Laboratory operations of the Pacific Northwest National Laboratory. Richland also manages the cooperative agreement with Associated Western Universities to administer research appointments at National Laboratories and universities, for undergraduate students and faculty, as part of the Office of Science funded Education Programs.

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 a national basic research laboratory, probing the structure of matter at the atomic scale with x-rays and at much smaller scales with electron and positron beams. SLAC scientists perform experimental and theoretical research in elementary particle physics using electron beams, plus a broad program of research in atomic and solid state physics, chemistry, biology, and medicine using synchrotron radiation. There are also active programs in the development of accelerators and detectors for high-energy physics research and of new sources and instrumentation for synchrotron radiation research. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Stanford Site Office

The Stanford Site Office provides institutional program management oversight in the execution of basic research at the Stanford Linear Accelerator Center, a national laboratory operated under a contract with Stanford University.

Thomas Jefferson National Accelerator Facility

Thomas Jefferson National Accelerator Facility (Jefferson Lab) is a program-dedicated laboratory (Nuclear Physics) located on 273 acres in Newport News, Virginia. Jefferson Lab is a basic research laboratory built to probe the nucleus of the atom to learn more about the quark structure of matter. The Laboratory gives scientists a unique and unprecedented probe to study quarks, the particles that make up protons and neutrons in an atom's nucleus. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Program Direction

Mission Supporting Goals and Objectives

The Program Direction subprogram provides the Federal staff and associated costs required for overall direction and execution of SC program and advisory responsibilities in Headquarters. The subprogram supports staff in the High Energy Physics, Nuclear Physics, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, Advanced Scientific Computing Research, Science Laboratories Infrastructure, and Energy Research Analyses programs, including management, resource, policy, and technical support staff. The staff includes scientific and technical personnel as well as program support personnel in the areas of budget and finance; general administration; grants and contracts; information technology; policy review and coordination; infrastructure management; construction management; safeguards and security; and environment, safety and health. Program Direction also includes resources to cover the costs of centrally provided goods and services procured through the Working Capital Fund at Headquarters, such as supplies, rent, telecommunications, desktop infrastructure, etc.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Headquarters					
Salaries and Benefits	32,369	37,527	38,136	+609	+1.6%
Travel	1,534	1,534	1,534	0	--
Support Services	7,408	7,275	6,384	-891	-12.2%
Other Related Expenses	6,520	10,670	12,170	+1,500	+14.1%
Total, Headquarters	47,831 [a]	57,006 [a]	58,224 [a]	+1,218	+2.1%
Total Excluding Full Funding for Federal Retirements, Program Direction	45,771	54,936	55,984	+1,048	+1.9%
Full Time Equivalents	268	293	299	+6	+2.0%

[a] The FY 2001 and FY 2002 columns of the FY 2003 Congressional Request include funding in the amount of $2,060 and $2,070, respectively, for the Government's share of increased costs associated with pension and annuitant health care benefits. These funds are comparable to FY 2003 funding of $2,240.

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Salaries and Benefits	**32,369**	**37,527**	**38,136**

This supports 299 Full Time Equivalents (FTEs) in Headquarters, six more than the FY 2002 comparable appropriation. The success of the Department's basic research programs is directly dependent on the viability of its scientific and technical workforce. By FY 2003, 33 percent of the SC workforce will be eligible to retire and increases to 45 percent by the end of FY 2005. SC is taking steps to preserve its technical, research, and scientific management capabilities. SC strives to attract highly qualified applicants to its workforce by offering these extraordinary candidates recruitment bonuses and using existing Federal personnel authorities to provide salaries comparable with the private sector. The justification for the six additional FTEs is as follows:

One FTE (1 of 6) is requested for a computer scientist to serve as the program manager for the Advanced Scientific Computing Research Scientific Discovery through the Advanced Computing (SciDAC) program. Currently there is one program manager who is managing two full-time efforts, the base computer science program in Mathematical, Information, and Computational Sciences and the computer science component of the SciDAC program. To ensure effective leadership of the computer science research portfolio for SC, an additional FTE is needed.

One FTE (2 of 6) is requested to support developments in the nanoscale arena. Funding and emphasis for nanoscale science will increase substantially in the future. In prior fiscal years, aspects of this research were included in many Basic Energy Science (BES) Core Research Activities, and a number of BES program managers administered this research. This diffused management worked until now. However, with the start of construction of three Nanoscale Science Research Centers (NSRCs) a dedicated program manager is required to coordinate the research, facility construction, and the eventual operation of the three research centers.

One additional FTE (3 of 6) is requested for a program manager with expertise in x-ray and neutron scattering. SC is experiencing increased activity in these areas that necessitates an additional FTE. The Stanford Synchrotron Radiation Laboratory at the SLAC will be upgraded to a third-generation light source thus increasing its capabilities and attracting a larger user population. Other areas of increased activity include, the High Flux Isotope Reactor at the ORNL that will be upgraded and result in one of the world's best steady-state neutron source. Instrument construction/upgrades will occur at the Manual Lujan, Jr. Neutron Scattering Center at Los Alamos National Laboratory. Instruments for the Spallation Neutron Source at ORNL will also be purchased. Other workload aspects include international activities with Japan and Europe and interactions with other agencies through standing Office of Science and Technology Policy interagency committees on synchrotron radiation and neutron scattering.

One FTE (4 of 6) is also requested for an additional program manager to support Chemical Reactivity and Chemical Theory/Modeling/Simulation activities. This is one of the largest Core Research Activities in BES. The emphasis has grown out of new directions in nano- and supramolecular chemistry and the need to understand and control chemical reactivity because of its impacts on the agency missions. Additional challenges involve complex gas phase reactions in the presence of surfaces and particulates and reactions in water and other solvents.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

An additional senior level, meteorologist/physical scientist FTE (5 of 6) is requested to support Climate Change Research within the Environmental Sciences Division of Biological and Environmental Research. This research directly underpins the DOE mission in National Energy Security and the Secretary's mission and priority to support the President's Climate Change Initiatives by developing models that predict what concentrations of trace atmospheric gases and aerosols result in unacceptable climate change. Advanced models will also provide enhanced capabilities necessary to detect and defend against the intentional release of hazardous chemical and biological agents to the atmosphere.

Lastly, a senior level geneticist/biological scientist (6 of 6) is needed to develop, implement, and manage the SC Genomes to Life Research program. This research directly underpins the DOE mission in National Energy Security and the Secretary's priorities by identifying and characterizing the structure and regulation of multiprotein complexes that carry out the biological functions of cells. This research will also help determine the functional capacity of complex microbial communities needed to develop biotechnology solutions for clean energy, carbon sequestration, environmental cleanup, and bioterrorism detection and defeat.

Travel..	**1,534**	**1,534**	**1,534**

Travel includes all costs of transportation of persons, subsistence of travelers, and incidental travel expenses in accordance with Federal travel regulations.

Support Services..	**7,408**	**7,275**	**6,384**

Provides funding for general administrative services and technical expertise provided as part of day-to-day operations and information technology (IT) maintenance and enhancements.

- Continue day-to-day operations within SC, e.g., mailroom operations; travel management; environment, safety and health support; security and cyber security support, and administering the Small Business Innovation Research program.

Standardize, integrate, and invest in IT that will best support improved mission accomplishment and promote IT efficiencies consistent with the provisions of the Information Technology Management Reform Act of 1996. SC provides a real-time computer Helpdesk, incorporates new technologies and maintains corporate systems that support grants management and other major business functions, e.g., improve Internet tools and make information and corporate systems more easily accessible; enhance cyber security capabilities; continue planned enhancements; and retire legacy systems – all as outlined in SC's Five-Year Information Management Strategic Plan.

Other Related Expenses..	**6,520**	**10,670**	**12,170**

Provides funds for a variety of tools, goods, and services that support the Federal workforce, including acquisitions made through the Working Capital Fund (WCF), computer and office equipment, publications, training, etc and continue support for the Corporate Research and Development (R&D) Portfolio Management Environment (PME).

For FY 2003, funding for PME is increased by $1,500,000. In total, $5,500,000 is requested in FY 2003 to proceed with modernizing and streamlining the Department's R&D management processes. Several modules are being developed in stages, e.g., R&D tracking, reporting, and program execution. In FY 2003, the requirements definition, design, and software for tracking and reporting (Module III) will be implemented ($4,000,000). The complete production environment will be in place (hardware, software, and communications) and will have an annual maintenance cost ($1,300,000). In addition, an Architectural Assessment Study is planned, to ensure compliance with DOE's Information Architecture as well as integration of the Corporate PME with existing information systems in the field and headquarters that will be supplying data ($200,000). Full PME implementation is to occur over a three-year period. DOE will be able to extract energy-related research data funded by various sources from a central reliable repository. The PME will become the technology infrastructure, providing information integration methodologies, and process enhancement that will enable electronic cradle-to-grave tracking of research projects, information sharing across programs, and snapshots of the Department's R&D. In the end, DOE will improve its management of R&D data, provide a corporate view across the complex, align with applicable laws and report information to Congress.

Total, Program Direction	**47,831**	**57,006**	**58,224**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Salaries and Benefits	
■ Supports 299 FTEs, 6 FTEs more than the comparable FY 2002 budget, includes the government's share of increased costs associated with pension and annuitant health care benefits, and factors a 2.6 percent pay adjustment in personnel compensation.	+609
Support Services	
■ Restructure support for information management activities.	-891
Other Related Expenses	
■ Continue Corporate Research & Development (R&D) Portfolio Management Environment (PME) efforts	+1,500
Total Funding Change, Program Direction	+1,218

Support Services

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Technical Support Services					
Test and Evaluation Studies	750	750	750	0	--
Total, Technical Support Services	750	750	750	0	--
Management Support Services					
ADP Support	5,538	4,975	4,084	-891	-17.9%
Administrative Support	1,120	1,550	1,550	0	--
Total, Management Support Services	6,658	6,525	5,634	-891	-13.7%
Total, Support Services	7,408	7,275	6,384	-891	-12.2%

Other Related Expenses

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Training	65	65	65	0	--
Working Capital Fund	4,004	4,205	4,205	0	--
Information Technology Hardware and Software/Maintenance Acquisitions	951	0	0	0	--
Other	1,500	6,400	7,900	+1,500	+23.4%
Total, Other Related Expenses	6,520	10,670	12,170	+1,500	+14.1%

Science Education

Mission Supporting Goals and Objectives

The **Science Education** subprogram supports four educational/human resource development programs. The Department is committed to programs that train students to enter careers in **S**cience, **M**athematics, **E**ngineering, and **T**echnology (SMET). Each of the subprograms targets a different group in order to attract as broad a range of students to the programs and to expand the pipeline of students who can enter the SMET workforce. In this fashion, the programs should help our National Laboratories and the nation meet the demand for a well-trained scientific/technical workforce. Because of the partnership between the Department and the National Science Foundation (NSF), research opportunities will be extended to community college faculty, enabling a broader and lasting impact on community college programs.

- The *Energy Research Undergraduate Laboratory Fellowship Program (ERULF)*, formerly known as the Laboratory Cooperative Program, is designed to provide workforce development through research experiences at DOE laboratories for highly motivated undergraduate students from any two or four year accredited college or university. These opportunities complement the students' academic training and introduce them to the unique intellectual and physical resources present at the DOE laboratories. Appointments are available during the spring, summer, and fall terms. These research opportunities have also been extended in collaboration with the National Science Foundation (NSF) to undergraduate students in NSF programs, including those who are preparing for teaching careers in science, mathematics or technology.
- The *National Science Bowl® Program* is a highly publicized academic competition among high school students who answer questions on scientific topics in astronomy, biology, chemistry, mathematics, physics, earth, computer and general science. This program was created to encourage high school students across the Nation to excel in math and science and to pursue careers in those fields. Since its inception, more than 70,000 high school students have participated in regional tournaments leading up to the national finals. This program provides the students, and teachers who have prepared them, a forum to receive national recognition for their talent and hard work.
- The *Albert Einstein Distinguished Educator Fellowship Program* supports outstanding science and mathematics teachers, who provide insight, extensive knowledge, and practical experience to the Legislative and Executive branches. This program is in compliance with the Albert Einstein Distinguished Educator Act of 1994 (signed into law in November 1994). The law gives DOE responsibility for administering the program of distinguished educator fellowships for elementary and secondary school mathematics and science teachers.
- The *DOE Community College Institute (CCI) of Science and Technology* provides a 10-week human resource development program through research experience at several DOE National Laboratories for highly motivated community college students. The CCI is targeted at underserved community college students who have not had an opportunity to work in an advanced science research environment. It incorporates both an individually mentored research component and a set of enrichment activities which include: lectures, classroom activities, career guidance/planning, and field trips. Appointments are available during the summer. These research opportunities have also been extended in collaboration with the National Science Foundation (NSF) to community college students and faculty in NSF programs.

Funding Schedule

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Energy Research Undergraduate Laboratory Fellowships	2,447	2,669	2,900	+231	+8.7%
National Science Bowl® Program	597	660	660	0	--
Albert Einstein Distinguished Educator Fellowship Program	810	460	500	+40	+8.7%
Community College Institute of Biotechnology, Environmental Science, and Computing	606	671	1,400	+729	+108.6%
Total, Science Education	4,460	4,460	5,460	+1,000	+22.4%

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Energy Research Undergraduate Laboratory Fellowships	**2,447**	**2,669**	**2,900**

The Energy Research Undergraduate Laboratory Fellowship (ERULF) Program is the oldest of the Science Education programs. The ERULF program supports a diverse group of students at our National Laboratories in individually mentored research experiences. Through these unique and highly focused experiences these students will comprise a repository of talent to help the DOE meet its science mission goals. The paradigms of the program are: 1) students apply on a competitive basis and are matched with mentors working in the students' fields of interest; 2) students spend an intensive 10-16 weeks working under the individual mentorship of resident scientists; 3) students must each produce an abstract and formal research report; 4) students attend seminars that broaden their view of career options and help them understand how to become members of the scientific community; and 5) program goals and outcomes are measured based on students' research papers, students' abstracts, surveys and outside evaluation. An undergraduate student journal was recently created which publishes selected full research papers and all abstracts of students in the program. The National Science Foundation (NSF) began a collaboration with this program as of FY 2001.

The program will ensure a steady flow of students with technical expertise into the Nation's pipeline of workers in both academia and industry. A system is being created to track students in their academic career paths.

A sub-component of the ERULF Program is the Pre-Service Teacher Program. The paradigms of the program are: 1) students apply on a competitive basis and are matched with mentors working the student's field of interest; 2) students spend an intensive 10 weeks working under the mentorship of master teachers and laboratory scientists to help maximize the building of content, knowledge, and skills through the research experience; 3) students must produce an abstract and an educational module

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

related to their research and may also produce a research paper or poster or oral presentation; 4) students attend professional enrichment activities, workshops and seminars that help students apply what they learn to their academic program and the classroom, and also to help them understand how to become members of the scientific community, and enhance their communication and other professional skills; and 5) program goals and outcomes are measured based on students' abstracts, education modules, surveys and outside evaluation. An undergraduate student journal was recently created which publishes selected full research papers and education modules and all abstracts of students in the program. The National Science Foundation entered into a collaboration with this program in FY 2001.

National Science Bowl ® Program	**597**	**660**	**660**

SC will manage and support the National Science Bowl® for high school students from across the country for DOE. Since its inception, more than 70,000 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. The National Science Bowl® provides the students and teachers a forum to receive national recognition for their talent and hard work. Saturday seminars in the latest scientific topics have been added to the National Science Bowl® weekend. Students participating in the National Science Bowl ® will be tracked to see the long-term impact on their academic and career choices.

Albert Einstein Distinguished Educator Fellowship Program..	**810**	**460**	**500**

The Albert Einstein Fellowship Awards for outstanding K-12 science, math, and technology teachers continues to be a strong pillar of the program for bringing real classroom and education expertise 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 Triangle Coalition for Science and Technology Education. The Triangle Coalition administers the program for the Department of Energy through the recruitment, application, selection and placement of the Einstein Fellows and evaluation of the program.

DOE Community College Institute of Biotechnology, Environmental Science, and Computing...	**606**	**671**	**1,400**

The DOE Community College Institute (CCI) of Science and Technology was originally a collaborative effort between DOE and its National Laboratories with the American Association of Community Colleges and specified member institutions. Through a recent Memorandum of Understanding with the NSF, undergraduate students in NSF programs are participating in this program and in FY 2002 the program will be open to students from all community colleges. This program is designed to address shortages, particularly at the technician and paraprofessional levels and will help develop the human resources needed to continue building the Nation's capacity in critical areas for the next century. The

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		

Institute provides a ten-week research fellowship for highly qualified community college students at a DOE National Laboratory. The paradigms of the program are: 1) students apply on a competitive basis and are matched with mentors working in the students' field of interest; 2) students spend an intensive 10 weeks working under the individual mentorship of resident scientists; 3) students must each produce an abstract and formal research report; 4) students attend professional enrichment activities, workshops and seminars that broaden their view of career options, help them understand how to become members of the scientific community, and enhance their communication and other professional skills; and 5) program goals and outcomes are measured based on students' research papers, students' abstracts, surveys and outside evaluation. An undergraduate student journal was recently created which publishes selected full research papers and all abstracts of students in the program. The National Science Foundation entered into a collaboration with this program in FY 2001. This allows NSF's undergraduate programs to include a DOE community college internship in their opportunities they provide to students.

	FY 2001	FY 2002	FY 2003
Total, Science Education	**4,460**	**4,460**	**5,460**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
■ Additional students and faculty will be supported under the ERULF program.	+231
■ Increase stipends for the Einstein Fellows and administrative expenses.	+40
■ Increase the number of students and faculty participating in the CCI program.	+729
Total Funding Change, Science Education	+1,000

Field Operations

Mission Supporting Goals and Objectives

The Field Operations subprogram enables the SC Field complex to manage programs, projects, laboratories, facilities, grants and contracts in support of science and technology, energy research, and environmental management activities under their purview.

In FY 2003, this Field Operations subprogram is the central funding source for all SC sponsored Federal field employees and the cost of administration within the field structure. The workforce manages and serves many different departmental missions at the Chicago and Oak Ridge Operations Offices and provides program management oversight for SC laboratories and facilities, e.g., Argonne, Brookhaven, Fermi, and Lawrence Berkeley National Laboratories; the Princeton Plasma Physics Laboratory; the Thomas Jefferson National Accelerator Facility; the Stanford Linear Accelerator Center; and the Spallation Neutron Source. Program oversight and safeguards and security functions performed in the Field were funded in the Program Direction subprogram prior to this FY 2003 realignment. In addition, several functions requiring technical support that were funded in the Oak Ridge Landlord activity in the Science Laboratories Infrastructure program are supported in this Field Operations subprogram: emergency management, directives management, training and development, and the Financial Service Center at Oak Ridge.

This subprogram provides Federal salaries and benefits for the following: financial stewardship, personnel management, contract and procurement acquisition, labor relations, security, legal counsel, public and congressional liaison, intellectual property and patent management, environmental compliance, safety and health management, infrastructure operations maintenance, information systems development and support, and reindustrialization.

In addition, this subprogram provides funding for the fixed requirements associated with rent, utilities, and telecommunications. Other requirements such as information technology maintenance, administrative support, mail services, document classification, personnel security clearances, emergency management, printing and reproduction, travel, certification training, vehicle acquisition and maintenance, equipment, classified/unclassified data handling, records management, health care services, guard services, and facility and ground maintenance are also included. These infrastructure requirements are relatively fixed. The Operations Offices are also responsible for supplying office space and materials for the Office of Inspector General located at each site. Other operational requirements funded include occasional contractor support to perform ecological surveys, cost validations, and environmental assessments; ensure compliance with Defense Nuclear Facilities Safety Board safety initiatives; abide by site preservation laws and regulations; and perform procurement contract closeout activities. Departmental and programmatic initiatives influence these requirements.

Integrating Headquarters functions with those of the Field, moving accountability from SC to the contractors through contracts that stipulate increased reliance on national standards and clarifying line management accountability offer the greatest opportunity for gains in efficiency and cost savings over the next few years. In broad terms, SC hopes to readjust its skills mix to reduce the number of positions required to provide contractor oversight. The optimum skill mix to support a streamlined office will depend upon SC's reengineering effort and the Department's ability to continue to move from a compliance-based oversight approach to one of performance-based.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	28,364	28,910	22,653	-6,257	-21.6%
Travel	699	639	639	0	--
Support Services	2,505	2,888	2,934	+46	+1.6%
Other Related Expenses	3,139	3,128	3,128	0	--
Total, Chicago Operations Office	34,707	35,565	29,354	-6,211	-17.5%
Full Time Equivalents	278	291	215	-76	-26.1%
Berkeley/Stanford Site Offices					
Salaries and Benefits	2,549	2,722	2,380	-342	-12.6%
Travel	130	130	130	0	--
Support Services	0	0	0	0	--
Other Related Expenses	600	600	600	0	--
Total, Berkeley/Stanford Site Offices	3,279	3,452	3,110	-342	-9.9%
Full Time Equivalents	19	26	23	-3	-11.5%
Oak Ridge Operations Office					
Salaries and Benefits	33,482	36,056	27,395	-8,661	-24.0%
Travel	524	524	524	0	--
Support Services	10,858	10,789	10,789	0	--
Other Related Expenses	4,720	4,623	4,623	0	--
Total, Oak Ridge Operations Office	49,584	51,992	43,331	-8,661	-16.7%
Full Time Equivalents	324	359	229	-130	-36.2%
Total Field Operations					
Salaries and Benefits	64,395	67,688	52,428	-15,260	-22.5%
Travel	1,353	1,293	1,293	0	--
Support Services	13,363	13,677	13,723	+46	+0.3%
Other Related Expenses	8,459	8,351	8,351	0	--
Total, Field Operations	87,570 [a]	91,009 [a]	75,795 [a]	-15,214	-16.7%
Total Excluding Full Funding for Federal Retirements, Field Operations	82,634	86,081	72,403	-13,678	-15.9%
Full Time Equivalents	621	676	467	-209	-30.9%

[a] The FY 2001 and FY 2002 columns of the FY 2003 Congressional Request include funding in the amount of $4,936 and $4,928, respectively, for the Government's share of increased costs associated with pension and annuitant health care benefits. These funds are comparable to FY 2003 funding of $3,392.

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Salaries and Benefits	**64,395**	**67,688**	**52,428**

Supports 467 FTEs within the SC field complex, 209 FTEs less than the comparable FY 2002 budget. Past forced and mostly unstructured downsizing across SC, combined with the recent reorganizations of DOE and its Field Offices, has left SC with under-staffing in some areas and over-staffing in others. To address this, SC is in the process of conducting a workforce reengineering study to address fundamental issues and functions within the Office. This study will design ways to maintain or improve SC's performance while reducing the cost of conducting its work, and will guide SC's plans for FTE reductions over the next two years. Some FTE reductions can be achieved through a combination of attrition, buyout and early retirement incentives, however, the majority must occur through involuntary separations. Funding is included to offset costs anticipated with these workforce reductions.

Travel	**1,353**	**1,293**	**1,293**

Enables field staff to participate on task teams, work various issues, conduct compliance reviews, and perform contractor oversight to ensure implementation of DOE orders and regulatory requirements at the facilities under their purview. Also provides for attendance at conferences and training classes, and permanent change of station relocation, etc.

Support Services	**13,363**	**13,677**	**13,723**

The field uses a variety of administrative and technical assistance services that are critical to their success in meeting local customer needs. The services provided support information technology (IT) routine computer maintenance, specific improvements, operating systems upgrades, and cyber security, network monitoring, firewalls, and disaster recovery tools. Other areas include staffing 24-hour emergency and communications centers, safeguarding and securing assets (guards, processing security clearances, classifying records, protecting assets and property, etc.), processing/distributing mail, travel management centers, contract close-out activities, copy centers, trash removal, directives coordination, facility and grounds maintenance, filing and retrieving records, etc.

The request includes support service activity previously budgeted under the Science Laboratories Infrastructure program (Oak Ridge Landlord account) and funding for SC's safeguards and security responsibilities at the Chicago Operations Office transferred from the Office of Security and Emergency Operations.

Other Related Expenses	**8,459**	**8,351**	**8,351**

Funds day-to-day requirements associated with operating a viable office, including fixed costs associated with occupying office space, utilities, telecommunications and other costs of doing business, e.g., postage, printing and reproduction, copier leases, site-wide health care units, records storage assessments, etc. Employee training and development and the supplies and furnishings used by the Federal staff are also included.

Total, Field Operations	**87,570**	**91,009**	**75,795**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Salaries and Benefits	
■ Supports 467 FTEs, 209 FTEs less than the comparable FY 2002 budget, as a part of a focused effort to restructure the Field Federal workforce; includes the government's share of increased costs associated with pension and annuitant health care benefits; and factors a 2.6 percent pay adjustment in personnel compensation	-15,260
Support Services	
■ Reflects the transfer of the safeguards and security function at Chicago from the Office of Security and Emergency Operations to SC.	+46
Total Funding Change, Field Operations	-15,214

Support Services

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Technical Support Services					
Economic and Environmental Analysis	0	0	0	0	--
Total, Technical Support Services	0	0	0	0	--
Management Support Services					
ADP Support	5,500	5,271	5,271	0	--
Administrative Support	7,863	8,406	8,452	+46	+0.5%
Total, Management Support Services	13,363	13,677	13,723	+46	+0.3%
Total, Support Services	13,363	13,677	13,723	+46	+0.3%

Other Related Expenses

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Training	620	620	620	0	--
Printing and Reproduction	336	255	255	0	--
Rent & Utilities & Telecommunication	4,430	4,620	4,620	0	--
Information Technology Hardware, Software, and Maintenance	847	577	577	0	--
Working Capital Fund	177	400	400	0	--
Other	2,049	1,879	1,879	0	--
Total, Support Services	8,459	8,351	8,351	0	--