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 15 passenger motor vehicles for replacement only, including not to exceed one ambulance, $3,310,935,000, to remain available until expended.

Note.—A regular 2003 appropriation for this account had not been enacted at the time the budget was prepared; therefore, this account is operating under a continuing resolution (P.L. 107–229, as amended). The amounts included for 2003 in this budget reflect the Administration's 2003 policy proposals.

Explanation of Change

Changes from the language proposed in FY 2003 consist of the addition of purchase authority for one ambulance and changes to the proposed motor vehicle and funding amounts.

Office of Science
Executive Summary

INTRODUCTION

The Office of Science (SC) requests $3,310,935,000 for the Fiscal Year 2004 (FY 2004) Science appropriation, an increase of $47,059,000 over FY 2003, for investments in basic research that are critical to the success of the Department of Energy (DOE) missions in: national security and energy security; advancement of the frontiers of knowledge in the physical sciences and areas of biological, environmental and computational sciences; and, provision of world-class research facilities for the Nation's science enterprise.

The Office of Science is the single largest supporter of basic research in the physical sciences, providing approximately 40 percent of all federal funds in this area over the past decade. It is also the steward, and by far the principal funding agency, of the nation's research programs in high-energy physics, nuclear physics and fusion energy sciences, as well as being the federal government's largest single funder of materials and chemical sciences. SC also supports unique or critical pieces of U.S. research in scientific computation, climate change, geophysics, genomics, and the life sciences. This research is conducted at both the DOE national laboratories and at approximately 250 universities nationwide. SC manages the construction and operation of some of the nation's most advanced R&D facilities - a vital part of the Nation's scientific infrastructure used by over 18,000 researchers annually.

The Nation's investment in the Office of Science has paid off handsomely. New materials have resulted in high energy batteries, the world's highest efficiency solar cells, and more efficient engines, while new catalysts have resulted in more energy-efficient industrial processes. The Administration has decided to enter negotiations to construct an international burning plasma experiment, based in large part on SC research and design efforts. Our high energy and nuclear physics programs are world leaders. SC initiated the Human Genome Project, and gave birth to the field of nuclear medicine and funded research that led to development of the positron emission tomography (PET) scan. SC is also essential to the education of the next generation of researchers: its grants to universities now support approximately 1/3 of all doctorates awarded in physical science.

Our economy, our energy security and our national security depend upon our scientific primacy. Beginning with the impact on technology development of scientific discoveries in chemistry and electromagnetism at the end of the 19^{th} century, scientific discovery has become the source of new technologies that are critically important to national security and economic progress. Today, advances in computing, communications and scientific instruments – many of them developed by SC – have transformed the conduct of science and created new scientific opportunities that promise revolutionary technologies to come.

> "*.....steady advances in the tools available for technical work have recently crossed a threshold of capability that open entirely new frontiers for scientific discovery, and provide unprecedented power for the analysis and solution of real-life problems*."
>
> Dr. John Marburger, Director, Office of Science and Technology Policy

The Office of Sciences' traditional strengths in scientific computing, construction and operation of scientific facilities, and management of large interdisciplinary programs of research will enable it to maintain continued world scientific leadership in the 21st century.

In FY 2004 the Office of Science will:

- Enter negotiations with representatives of the European Union, Japan and Russia on construction and operation of a burning plasma experiment - the International Thermonuclear Experimental Reactor (ITER).

- Continue to build on its leadership in high performance computing and networking to bring the full potential of scientific computation to bear on the Department's scientific problems. It will initiate a Next Generation Computer Architecture program to identify and address performance bottlenecks in existing and planned systems.

> *"…development of capabilities in high-end scientific computation will enable U.S. industries in general and General Motors in particular to significantly reduce the time-to-market of their products and services. A computing architecture and capability in the order of 100 Teraflops for example would have quite an economic impact, on the order of billions of dollars, in the commercial sector and in its product design, development and marketing."*
>
> Tony Scott, Chief Technology Officer
> General Motors Information Systems and Services

- Continue construction of the Spallation Neutron Source, proceed with construction of three Nanoscale Science Research Centers (NSRCs) and initiate work on two others. These NSRCs located at national laboratories in New York, Tennessee, Illinois, New Mexico and California will provide scientists with an unmatched set of tools to design and build complex nanoscale materials.

- Exploit its unique capabilities at the intersection of the physical sciences, the life sciences and scientific computation to continue and expand its effort to understand how the instructions embedded in genomes control the development of organisms, with the goal of harnessing the capabilities of microbes and microbial communities to help us to produce energy, clean up waste, and sequester carbon from the atmosphere.

- Initiate a Laboratory Science Teacher Professional Development program for K-14 teachers in science and mathematics. Teachers will be competitively selected for a 4-8 week mentoring program by both scientists and master teachers at a national laboratory, followed by both additional 1 week mentoring visits and long term continuing support.

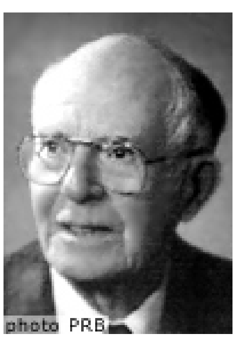
- Exploit the capabilities of the world's finest set of research facilities in particle physics to attempt to find the answers to questions about matter and energy at the most fundamental level. What gives elementary particles their great variety of masses? Are there extra dimensions of space beyond the three we know? Why is there so little antimatter in the universe when we expect equal amounts of each were created in the Big Bang? What is the Dark Energy that causes the recently observed acceleration in the expansion of the universe and comprises fully two thirds of the mass and energy budget of the universe? What were the properties of the early universe before quarks and gluons condensed into protons and neutrons?

HISTORY OF SUCCESS

The Office of Science can trace its roots to the original legislation creating the Atomic Energy Commission in 1947, which had a charter to use fundamental research in nuclear physics and other physical sciences towards "…improving the public welfare, increasing the standard of living, strengthening free competition in private enterprise, and promoting world peace." More than five decades later, the Office of Science can point to an extraordinary and diverse array of scientific discoveries that have led to dozens of Nobel Prizes, a draft map of the Human Genome, the creation of "Bucky Balls", discovery of the quark structure of matter and the "Accelerating Universe," major breakthroughs in medical diagnoses and nuclear medicine, and providing tools that allow researchers to "see" at the atomic and subatomic scales, to simulate complex interactions and to collaborate across great distances.

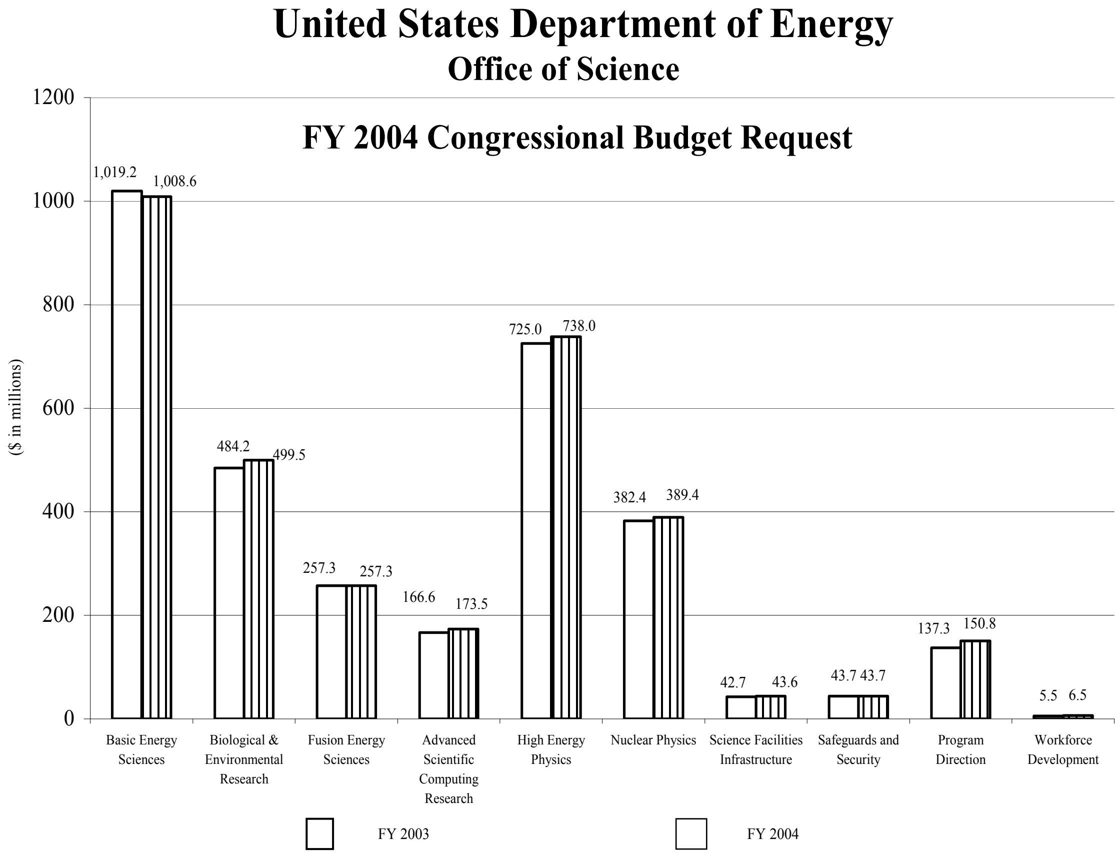
That history of discovery (which is documented on the Office of Science website, www.er.doe.gov/feature_articles_2001/June/Decades/index.html) continues to this day, with major accomplishments in the past year that are the result of the long-term, high-risk, multidisciplinary research sponsored by SC and the strong management practices of the dedicated and highly skilled SC workforce.

Two achievements in 2002 stand out as representative of the scope and magnitude of the research sponsored by SC. First is a technological miracle– restoring sight to the blind – being developed through an extraordinary marriage of biology and the physical sciences. The combination of diverse scientific disciplines such as these is a hallmark of SC research and a particular strength of the DOE national laboratories. But realizing this remarkable technology also relies on the unique capabilities of Industry (Second Sight, located in Santa Clarita, Calif.) and Academia (the Doheney Eye Institute at the University of Southern California and North Carolina State University) in partnership with the national laboratories. In this project, specially designed MEMs (microelectro-mechanical systems) electrodes are positioned on the retinas of patients who have been blinded by disease, enabling them to convert light to electrical pulses that are received by the brain. Today's prototype enables a formerly blind patient to distinguish light from dark. Tomorrow's technology has the potential to restore almost full sight to the 200,000 people in the U.S. who are blinded every year by macular degeneration. This miracle of science is possible due to the long-term commitment of dedicated teams of scientists supported by SC.



The second was the award of the 2002 Nobel Prize for Physics shared by Raymond Davis, Jr., whose sublime experiments led to the capture of solar neutrinos, proving that fusion provides the Sun's energy and leading to the creation of an entirely new field of research: neutrino astronomy. Davis did his groundbreaking work while a researcher at SC's Brookhaven National Laboratory, which is home to multiple Nobel Prize recipients. This is the most recent of the Nobel Prizes that have been awarded to DOE-supported scientists.

In its announcement of the Nobel Prize citation, the Royal Swedish Academy of Sciences said of Davis's accomplishment: "This year's Nobel Laureates in Physics have used these very smallest components of the universe (neutrinos) to increase our understanding of the very largest: the Sun, stars, galaxies, and supernovae. The new knowledge has changed the way we look upon the universe."



FY 2004 PROGRAM SPECIFIC INITIATIVES

The **Advanced Scientific Computing Research** (ASCR) program underpins DOE's ability to accomplish its mission through scientific computation. The ASCR program supports research in applied mathematics, computer science and high-performance networks and provides high-performance computational and networking resources to enable the advancement of the leading edge science that the DOE mission requires. ASCR delivers the power of advanced scientific computation and networking to the wide array of scientific disciplines supported by SC.

In FY 2004, ASCR will embark on research to identify, address and correct bottlenecks that presently constrain DOE's capabilities in modeling and simulation. A research portfolio in Next Generation Computer Architecture will be initiated to assess novel computer architectures and their prospects for achieving optimal performance on DOE's scientific simulations.

In FY 2004, the ASCR program will continue to develop the underlying mathematical algorithms, software building blocks and infrastructure for the "Scientific Discovery through Advanced Computing," (SciDAC) program. SciDAC is an Office of Science research endeavor to produce the scientific computing, networking and software that DOE researchers will need for sustained progress at the scientific forefront in areas of strategic importance to the Department. The scope of the SciDAC program will be extended to include new activities to address the urgent need for a quantitative understanding of matter at the nanoscale.

The ASCR program will also maintain the vitality of its basic research efforts in applied mathematics, computer and computational science, and network research to bolster the foundation for continued success in advancing scientific frontiers through computation.

In FY 2004, the Genomes to Life research activities in partnership with the Biological and Environmental Research program will be expanded to include new research in the applied mathematical sciences that will develop new computational techniques for the study of regulatory networks and metabolic pathways for microbial systems.

Finally, in FY 2004, ASCR will provide high performance computing and networking resources at the levels needed to meet SC needs. The National Energy Research Scientific Computing Center, as a result of an enhancement in FY 2003, will be operated at 10Tflops to meet the computational needs of nearly 2,400 users. The Energy Sciences Network (ESnet) will be operated to provide state of the art network services and capabilities to DOE-supported researchers to collect, analyze, visualize and distribute large-scale scientific data sets.

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 2004, construction will proceed on three Nanoscale Science Research Centers (NSRCs), project engineering design will be initiated on the fourth NSRC, and a Major Item of Equipment will be initiated for the fifth and final NSRC. NSRCs are user facilities for the synthesis, processing, fabrication, and analysis of materials at the nanoscale. The five NSRCs will be located strategically at national laboratories across the country in New York, Tennessee, Illinois, New Mexico, and California. These facilities, in conjunction with existing user facilities at these national laboratories, will provide a strikingly unique suite of forefront capabilities where the Nation's leading scientists can design and build complex nanoscale materials all in one place.

The five NSRCs will be the Nation's critical focal points for the development of the nanotechnologies that will revolutionize science and technology. They will provide state-of-the-art nanofabrication equipment and quality in-house user support for hundreds of visiting researchers. The Centers will provide an environment for research of a scope, complexity, and disciplinary breadth not possible under traditional individual investigator or small group efforts. As such, the DOE Centers will be the training grounds of choice for the top graduate students and elite postdoctoral associates who will lead the future of scientific research.

A high priority in FY 2004 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 half of the work completed as of the end of FY 2002. At the end of FY 2004, construction of the SNS will be 80% complete.

Today, we have unprecedented opportunities to use advances in biology, computation, engineering, physics, and chemistry, to develop new solutions for challenges in energy, the environment, and health. The **Biological and Environmental Research (BER)** program is bringing these diverse fields together at DOE laboratories, universities, and private research institutes to find innovative approaches along unconventional paths to address DOE challenges.

In FY 2004, the Genomes to Life program continues to develop novel research and computational tools that, when combined with our genomics, structural biology, and imaging research provide a basis to understand and predict responses of complex biological systems. Other BER efforts in the Life Sciences include Human Genome research and DNA sequencing and Low Dose Radiation research.

BER contributions to the President's Climate Change Science program include research in climate modeling, atmospheric composition, and regional impacts of climate change. Carbon cycle research will work toward understanding what fraction of carbon dioxide emissions are taken up by terrestrial ecosystems. New in FY 2004, are ecological research efforts to begin to bridge the knowledge gap between molecular level effects and the responses of entire ecosystems to natural and human-induced environmental changes.

A key challenge in Environmental Remediation Science is to understand the subsurface environment and to then develop innovative options for clean up and protection. In FY 2004, BER research will continue to develop new cleanup strategies, including bioremediation of metals and radionuclides and the treatment and disposal of high-level radioactive wastes stored in large underground tanks. The Environmental Molecular Sciences Laboratory is maintained at the leading edge of computational capabilities for enhanced modeling of environmental and molecular processes.

Because of DOE's diverse capabilities across a range of scientific disciplines, BER Medical Sciences research will continue to provide the medical community with novel devices and technologies to detect, diagnose, and treat disease. One example is research that will develop the capability to detect genes as they are turned on and off in any organ in the body with enormous impacts in developmental biology and the diagnosis of disease.

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 National Energy Policy states that fusion power has the long-range potential to serve as an abundant and clean source of energy and recommends that the Department develop fusion. The next frontier in the quest for fusion power is sustained, burning (or self-heated) plasma. The Fusion Energy Sciences Advisory Committee (FESAC) has concluded that the fusion program is ready to proceed and has recommended joining the ongoing negotiations to construct the international burning plasma experiment, ITER. The National Research Council (NRC) of the National Academy of Sciences has endorsed this strategy. Based on these recommendations and an SC reviewed cost estimate for the construction of ITER, the President has decided to join the ITER negotiations.

Four areas characterize the FES program activities for FY 2004 and beyond. These are *Burning Plasmas*, which will include our efforts in support of ITER; *Fundamental Understanding*, which includes theory, modeling, and general plasma science; *Configuration Optimization*, which includes experiments on advanced tokamaks, advanced magnetic configurations, and inertial fusion concepts, as well as facility operations and enabling R&D; and *Materials and Technology*, which includes fusion specific materials research and fusion nuclear technology research. Integrated progress in all of these thrust areas is required for ultimate success in achieving a practical fusion energy source.

In light of the President's decision to join the ITER negotiations, many elements of the fusion program that are broadly applicable to burning plasmas will now be directed more specifically toward the needs of ITER which will be the focal point of burning plasma fusion research around the world. The U.S.

funding commitment to ITER will increase significantly in the out years as the project moves to construction and eventually to science operations. These increases are consistent with the recommendations of the December 20, 2002, NRC interim report on Burning Plasma.

The FY 2004 budget supports the program balance and priorities recommended by FESAC and supported by the Secretary of Energy Advisory Board and the NRC. The FY 2004 budget request supports continuing the final design and initial fabrication of the National Compact Stellarator Experiment facility at Princeton Plasma Physics Laboratory.

The President's decision to join the ITER negotiations to build a burning plasma experimental facility will require that the longer range technology activities be curtailed to allow a focus on program elements that most directly support preparations for ITER construction, in particular, the operation of existing facilities. The majority of existing and proposed program elements already contribute to tokamak science, thereby providing a strong base for our future contributions to and ability to benefit from ITER.

Whether or not a burning plasma experiment will be realized through the construction and operation of the proposed ITER device will depend on the success of the international negotiations in determining an agreed-upon site for the facility, an agreed-upon financial and procurement arrangement, and satisfactory management and oversight arrangements. In these negotiations, the U.S. will strive for incorporation of its principles of equity, accountability and transparency, which will be an important part of any decision-making process for joining any future construction project. Should the ITER project not proceed to fruition or if the U.S. cannot accept the eventual terms, FESAC has recommended that the U.S. fusion program continue toward a burning plasma experiment, using the FIRE concept (a fusion research experiment to explore the science of short duration burning plasmas) by seeking partnership from within the international fusion community. Specific burning plasma tasks outlined in this budget proposal are supportive of ITER and would also be supportive of FIRE, as the technical physics issues are similar.

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. Until 2007, when Europe's Large Hadron Collider (LHC) is scheduled to begin operations, the U.S. is the primary world center for HEP research. In FY 2004, the HEP program will concentrate on facility utilization, including direct support for researchers, as well as incremental facility upgrades.

In FY 2004, the Fermilab Tevatron Collider Run II will be in full swing, with an ultimate goal of discovering the long-sought Higgs particle, thought to be the key to understanding why particles have mass. But en route to that goal, the Run II program will in the near term enable many advances and discoveries at the energy frontier, including providing much more information about the heaviest known particle, the top quark, discovered at Fermilab in 1995; discovery or elimination of an entirely new class of particles, predicted by many theories to be present in Run II data; or even unfolding of the undiscovered space-time dimensions that have been postulated to complete the unification of fundamental interactions. A series of planned upgrades to the Tevatron accelerator complex, the major detectors, and computing facilities will continue in FY 2004 in order to enable a vigorous physics program that will maintain Fermilab's scientific leadership through the end of the decade. In addition, the Neutrinos at the Main Injector (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.

Building on the outstanding performance of the B-factory at the Stanford Linear Accelerator Center (SLAC), the HEP program will increase support for operation of the B-factory in FY 2004 to break new ground in exploring the source and nature of matter-antimatter asymmetry in the B-meson system. The upcoming round of experimental results may provide evidence for new physics beyond the Standard Model of particle physics. Incremental upgrades are also planned in FY 2004 for the accelerator to improve physics output and for the computing capabilities to cope with high data volumes.

Continued U.S. participation in the LHC project at CERN is a high priority in FY 2004. The U.S. contributions to the LHC accelerator and the ATLAS and CMS detectors are on schedule and within budget for the scheduled start-up date of 2007. Focus of this effort will begin to shift in FY 2004 from construction to pre-operations for the U.S.-built detector components and to developing the software and computing infrastructure necessary to exploit LHC physics.

Progress continues on particle astrophysics experiments and R&D in partnership with NASA. Collaborations on the Alpha Magnetic Spectrometer (AMS) and the Large Area Telescope (LAT), part of the Gamma-Ray Large Area Space Telescope (GLAST) mission, will be engaged in full detector fabrication and assembly in FY 2004. The SuperNova Acceleration Probe (SNAP) will begin fabrication of detector prototypes in support of a 2006 Conceptual Design. These experiments are working toward understanding diverse phenomena in astrophysics and cosmology, including dark energy, high energy gamma ray sources, and antimatter in space, all of which play a role in the story of the origin and fate of the Universe.

In addition, the program continues to support advanced technology R&D in FY 2004 geared toward future accelerators, including a high-energy, high-luminosity Linear Collider to complement and extend the physics program of the LHC. In January 2002, the HEPAP Subpanel on Long Range Planning stated that such a collider should be the highest priority of the U.S. HEP program.

The **Nuclear Physics** (NP) program supports fundamental nuclear physics research, providing about 90% of Federal support for this field. NP research advances our knowledge of the properties and interactions of atomic nuclei and nuclear matter in terms of the fundamental forces and particles of nature. It also supports the scientific knowledge-base, technologies and trained manpower that are needed to underpin DOE's missions for nuclear-related national security, energy, and the environment.

The NP program seeks answers to questions in three broad areas. (1) The basic constituents of nuclei, the neutrons and protons (nucleons) are themselves each composed of three quarks and the gluons that "carry" the strong force between them. Yet, these quarks are "confined" and cannot be found individually in nature. Understanding this confinement and the transition from a nucleon to quark description of nuclear structure is a central question of the field. (2) The early universe, up to a millionth of a second after the "Big Bang", is believed to have been a soup of quarks and gluons, a quark-gluon plasma. Creation of microcosms of this primordial matter in the laboratory is now being attempted in order to answer how the universe evolved at the very beginning of time. (3) The chemical elements are believed to have been created in stars and supernovae explosions, yet the nuclear reactions involved in this process involve nuclei far from the naturally occurring ones on earth. To answer how the elements were made (nucleosynthesis) requires producing exotic radioactive nuclear beams. Understanding the dynamics of supernovae also requires understanding the properties of the elusive neutrino which can only be detected in massive detectors.

In FY 2004, the NP program will focus on enhancing the operations of the program's user facilities, especially the Relativistic Heavy Ion Collider (RHIC), so as to bring all operating facilities to about 83 percent of optimal utilization. This will increase beam hours for research by about 5 percent over the FY 2003 Request. Operation of the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory is terminated in FY 2004. Nuclear Theory, new Low Energy instruments, and increased support to non-accelerator research such as neutrino experiments are also strongly supported.

In addition to increased operations at RHIC, FY 2004 funding will support an aggressive experimental program with the newly completed G0 detector at Thomas Jefferson National Accelerator Facility (TJNAF) to begin to map out the strange quark contribution to the structure of the nucleon. The MIT/Bates research program with the BLAST detector is being initiated in FY 2003 with completion planned in FY 2004. The two Low Energy user facilities (ATLAS and HRIBF) will also increase running schedules in FY 2004 for nuclear structure and astrophysics studies.

In FY 2003-2005, the Sudbury Neutrino Observatory (SNO) will make 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 **Science Laboratories Infrastructure (SLI)** program plays a vital role in enabling the continued performance of world-class research 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. In FY 2004 SLI will support six ongoing projects and one new start - seismic safety and operational reliability improvements at the Stanford Linear Accelerator Center (SLAC). Excess Facilities Disposition (EFD) subprogram funds will accelerate disposition of both contaminated and non-contaminated excess SC facilities, resulting in reduction of costs and risks while freeing-up valuable land. The FY 2004 Budget Request also includes funding for the Oak Ridge Landlord subprogram.

Safeguards and Security reflects SC's commitment to maintain adequate protection of cutting edge scientific resources. In FY 2004, Safeguards and Security will enable SC labs to meet the requirements of maintaining approved Security Condition 3 level mandates for the protection of SC assets. Integration of security into the laboratories' systems and continued risk management are also supported. In addition, critical cyber security tools and software will be purchased to respond to the ever changing cyber threat.

Workforce Development for Teachers and Scientists supports three subprograms: Pre-College Activities such as the National Science Bowl; the Undergraduate Research Internships for undergraduate students wishing to enter science, technology and science teaching careers; and Graduate/Faculty Fellowships for K-16 teachers of science, technology, engineering, and mathematics (STEM). Each of the sub-programs targets a different group of students and teachers in order to attract a broad range of participants to the programs and expand the nation's supply of well-trained scientists and engineers. Focus of this program is on the Physical Sciences and other areas of research which underpin the DOE missions and have, over the last decade, seen a marked decline in the numbers of undergraduate degrees awarded. Initiated in FY 2004 is the Laboratory Science Teacher Professional Development program that will provide long-term scientific community support from our National Laboratories for K-14 STEM teachers.

Science Program Direction enables a skilled, highly motivated Federal workforce to manage SC's research portfolio, programs, projects, and facilities in support of new and improved energy, environmental, and health technologies, and to provide continuous learning opportunities. Science Program Direction consists of four subprograms: Program Direction, Field Operations, Technical Information Management (TIM) and Energy Research Analyses (ERA).

The Program Direction subprogram supports Federal staff in Headquarters responsible for directing, administering, and supporting the broad spectrum of scientific disciplines. The Field Operations subprogram is the funding source for the Federal workforce in the Field complex responsible for providing business, administrative, and specialized technical support to DOE programs. The TIM subprogram collects, preserves, and disseminates the scientific and technical information of the DOE. The ERA subprogram provides the capabilities needed to evaluate and communicate the scientific excellence, relevance, and performance of SC basic research programs.

As part of the Restructuring effort, SC will focus on its Federal human capital in FY 2004 to effectively respond to the science needs of the future and to the challenge of an anticipated 50 percent turnover of retirement-eligible senior scientists over the next five years. Also in FY 2004, SC continues to support a corporate DOE information management system, the Electronic R&D Portfolio Management Tracking and Reporting Environment (ePME), which enables end-to-end tracking of research projects, information sharing across programs, and snapshots of the Department's R&D portfolio. ePME will integrate with the e-Grants functions of e-Government, the Department's e-Financial Management System, and the e-Procurement Modernization System.

A Vision for the Future

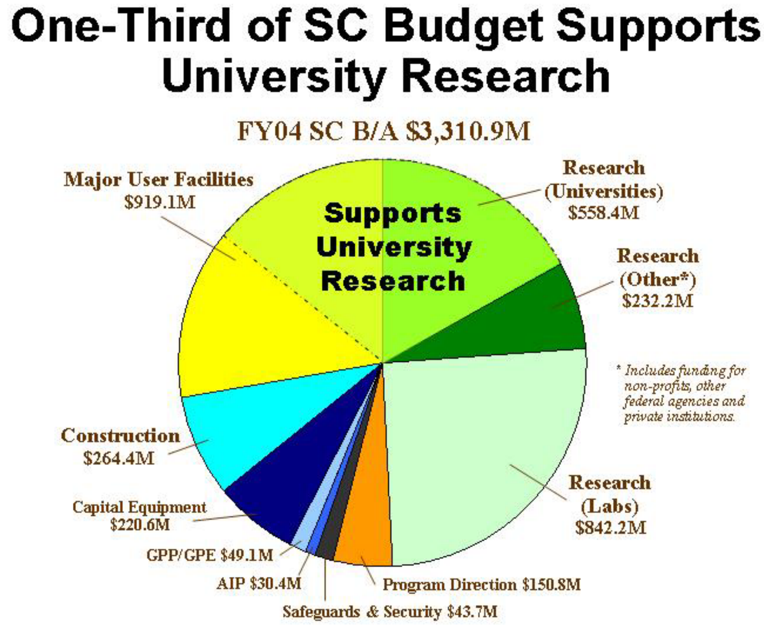
SC sponsors research that often involves long time scales and requires a clear strategy. Raymond Davis, for example, conducted his seminal research over a 30-year time period and was highly focused on a goal that many others thought was beyond the technology of the time. His work built on the prediction by Wolfgang Pauli, in 1930, that neutrinos exist and has led to other path breaking research including the announcement in 2001, by a team including SC supported researchers, that neutrinos oscillate among three distinct types during their journey from the Sun to the Earth, thus helping to explain the perceived absence of solar neutrinos. This discovery also challenged long-held views regarding whether neutrinos have mass.

The Department's emerging strategic direction for SC focuses on three long-range goals. These goals are being brought to life through the investments made in this FY 2004 budget request:

- *DOE-sponsored research leads the world in scientific advances in energy-related basic sciences.*
- *DOE is the recognized leader in the integration of the physical sciences, biology, and engineering, providing innovative interdisciplinary approaches and technologies that improve human health.*
- *DOE is the major provider of the Nation's research facilities for the physical sciences and computation, and contributes unique, vital facilities to the biological and environmental sciences.*

SC's vision for the next five years will be articulated in a new Strategic Plan, which will be issued in early 2003. The Plan will detail future scientific directions within the Office of Science for DOE missions and for our Nation. Key to development of that Strategic Plan is consistency with the Department's missions and objectives, a deep understanding of the scientific challenges that will face our Nation during the 21st Century, and maximization of the limited resources available to the Department.

How We Manage our Programs



SC manages a significant portion of the Nation's R&D enterprise and is the single largest supporter of basic research in the physical sciences in the United States, providing more than 40 percent of total funding for physics, chemistry, materials science and other areas of the physical sciences. SC also manages research at 10 national laboratories and the world's most diverse portfolio of unique and powerful scientific tools – including particle accelerator centers, neutron sources, high-powered light sources, advanced computational centers, and atmospheric monitoring facilities. In addition, SC funds more than 7,000 individual research projects at universities, national laboratories, U.S. industry and the non-profit sector. Fully one-third of the SC budget supports university research.

All told, more than 25,000 highly skilled scientists, technicians and engineers depend upon SC's stewardship of vital scientific resources – either through direct support or through access to scientific user facilities. Managing this complex research portfolio requires hard choices about areas of science to fund, constant communication with the scientific community, and an ability to meet the challenges that affect SC's management of these resources.

SC relies upon the expert opinions of the U.S. scientific community to set priorities, particularly through the use of six independent advisory committees, extensive competition through grants and contracts for the best qualified scientific talent and ideas, and through the peer review of virtually all of the scientific proposals that are eventually funded.

Embracing the President's Management Agenda

The President's Management Agenda (PMA) articulates a performance management framework that the Office of Science is adopting at all levels of its management structure. The PMA is leading to major restructuring in four areas:

> *"What matters in the end is completion. Performance. Results. Not just making promises, but making good on promises. In my Administration, that will be the standard, from the farthest Regional Office of government to the highest office of the land."*
>
> President George W. Bush

Management of Human Capital: In FY 2002, SC initiated a Workforce Restructuring Project to define the principles by which SC and its Field sites will operate and to clarify roles, responsibilities, authorities and accountabilities across the entire organization. This effort will improve the management and implementation of programs by reducing layers of management, streamlining decision-making processes, clarifying lines of authority, and utilizing resources more efficiently throughout SC and its Field sites. The changes planned are consistent with both the President's Management Agenda and SC's Business Vision. The Restructuring Project will determine staffing needs throughout the SC complex.

Competitive Sourcing: Through a series of competitive sourcing studies, the DOE will review 927 federal positions in FY 2002-FY 2003 to evaluate whether the necessary services provided should be provided by federal employees or by the private sector. More than 170 positions are being studied at SC sites.

Expanded E-Government: By the end of FY 2004, 100% of grant and contract proposals will be received electronically by SC, 65% of purchase orders will be done electronically, and 80% of field budget information will be processed electronically - including 100% of new projects.

Budget & Performance Integration: For the second year, SC has included in the Budget Request, detailed performance information (including annual targets) aligned with major program goals.

Program Assessment Rating Tool (PART)

In implementing the PMA, the Office of Management and Budget (OMB) developed the PART to assess the *purpose, planning, management,* and *performance* of Federal programs. The six SC research programs each completed a PART analysis for the FY 2004 budget request. All of the SC programs received perfect scores in the *purpose* section and generally very high scores in the *management* section. These high scores are due to standard management practices across SC that result in programs with well defined missions, merit-based reviews for awarding contracts and grants, and highly-regarded large-scale project management practices. However, all of the SC programs were assessed "results not demonstrated". The primary cause for this, and for the generally lower scores in the *planning* and *results* sections, is that OMB and SC have not yet reached agreement on the appropriate long-term and annual performance measures for SC basic research programs. OMB has acknowledged that establishing practical and meaningful performance measures for basic research is inherently difficult because of the largely unpredictable nature of scientific inquiry and the great deal of variation across scientific disciplines. SC has worked with OMB, invested in research into science performance measurement, and hosted interagency working group meetings to improve performance metrics. SC expects to resolve the issue in FY 2004 through the development, validation, and implementation of a suite of long-term and annual performance measures for federal research.

"...some of the most interesting problems are decade-long problems or multi-decade-long problems and they can be really worth that investment..."

"...having a sustained source of consistent funding is really extremely important in all areas of science..."

"By taking some risks, trying to do things that aren't necessarily quite so clear but that have potentially huge payoffs, rewards can be very great."

2002 Lawrence Award Winners Perlmutter, Brinker and Hodgson

Dr. Raymond L. Orbach
Director
Office of Science

Table 1

OFFICE OF SCIENCE

FY 2004 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

	FY 2002 Comparable Appropriation	FY 2003 Comparable President's Request	FY 2004 President's Request
Science			
Basic Energy Sciences	979,560	1,019,163	1,008,575
Advanced Scientific and Computing Research	150,205	166,557	173,490
Biological and Environmental Research	554,125	484,215	499,535
Fusion Energy Sciences	241,100	257,310	257,310
High Energy Physics	697,383	724,990	737,978
Nuclear Physics	350,589	382,370	389,430
Science Laboratories Infrastructure	37,125	42,735	43,590
Science Program Direction	149,467	137,332	150,813
Workforce Development for Scientists and Teachers	4,460	5,460	6,470
Small Business Innovation Research and Small		-	-
Business Technology Transfer	99,668	-	-
Subtotal	3,263,682	3,220,132	3,267,191
Safeguards and Security			
Safeguards and Security	50,230	48,127	48,127
Reimbursable Work	(4,460)	(4,383)	(4,383)
Total, Safeguards and Security	45,770	43,744	43,744
Total Science	3,309,452	3,263,876	3,310,935

Table 2

OFFICE OF SCIENCE
FY 2004 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

	FY 2002 Comparable Appropriation	FY 2003 Comparable President's Request	FY 2004 President's Request
Genomes to Life	21,696	42,414	66,906
U.S. Global Climate Change Research Program	117,329	126,169	108,104
Climate Change Research Initiative	-	2,920	25,335
High Performance Computing and Communications	168,148	182,636	190,068
Nanoscience Engineering and Technology	88,726	133,040	196,541
Workforce Development for Teachers and Scientists	4,460	5,460	6,470

Table 3

Institutional General Plant Projects

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Oak Ridge National Laboratory	1,225	6,000	6,000	+0	+0.0%
Pacific Northwest National Laboratory	0	1,000	3,000	+2,000	+200.0%
Total, Institutional General Plant Projects	1,225	7,000	9,000	+2,000	$28.6%

Table 4

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

Major Site Funding	FY 2002 Comparable Appropriation	FY 2003 Comparable President's Request	FY 2004 President's Request
AMES LABORATORY			
Advanced Scientific and Computing Research	2,183	1,625	1,578
Basic Energy Sciences	18,377	16,507	16,502
Biological and Environmental Research	830	512	555
Safeguards and Security	397	409	409
Total Laboratory	21,787	19,053	19,044
ARGONNE NATIONAL LABORATORY			
Advanced Scientific and Computing Research	13,503	8,573	11,646
Basic Energy Sciences	156,916	152,734	166,066
Biological and Environmental Research	24,446	22,970	23,295
Fusion Energy Sciences	1,662	1,522	1,192
High Energy Physics	9,849	10,293	10,043
Nuclear Physics	18,453	17,548	18,709
Safeguards and Security	7,679	7,809	7,809
Science Laboratories Infrastructure	3,643	4,205	6,002
Workforce Development for Teachers & Scientists	430	615	570
Total Laboratory	236,581	226,269	245,332
BROOKHAVEN NATIONAL LABORATORY			
Advanced Scientific and Computing Research	1,359	542	960
Basic Energy Sciences	59,158	57,398	61,755
Biological and Environmental Research	23,749	16,248	14,964
High Energy Physics	39,117	23,319	21,161
Nuclear Physics	140,108	149,004	149,588
Safeguards and Security	10,916	10,970	10,970
Science Laboratories Infrastructure	7,413	8,513	5,917
Workforce Development for Teachers & Scientists	430	615	522
Total Laboratory	282,250	266,609	265,837

	FY 2002 Comparable Appropriation	FY 2003 Comparable President's Request	FY 2004 President's Request
FERMI NATIONAL ACCELERATOR LABORATORY			
Advanced Scientific and Computing Research			
Energy Research Analyses	326	60	226
High Energy Physics	306,782	313,200	304,663
Nuclear Physics	231	-	-
Safeguards and Security	2,684	2,837	2,837
Science Laboratories Infrastructure	53	-	233
Workforce Development for Teachers & Scientists	20	100	50
Total Laboratory	310,096	316,197	308,009
IDAHO NATIONAL ENGINEERING LABORATORY			
Basic Energy Sciences	1,784	1,494	1,494
Biological and Environmental Research	2,428	2,205	3,400
Fusion Energy Sciences	2,356	2,392	1,823
Workforce Development for Teachers & Scientists	10	-	100
Total Laboratory	6,578	6,091	6,817
LAWRENCE BERKELEY NATIONAL LABORATORY			
Advanced Scientific and Computing Research	65,872	53,223	57,686
Basic Energy Sciences	81,885	78,691	108,247
Biological and Environmental Research	72,102	42,786	53,055
Fusion Energy Sciences	5,952	5,799	5,718
High Energy Physics	43,284	32,530	39,183
Nuclear Physics	19,943	18,615	15,840
Safeguards and Security	4,706	4,753	4,753
Science Laboratories Infrastructure	6,900	5,607	2,975
Science Program Direction	-	50	100
Workforce Development for Teachers & Scientists	505	750	600
Total Laboratory	301,149	242,804	288,157

	FY 2002 Comparable Appropriation	FY 2003 Comparable President's Request	FY 2004 President's Request
LAWRENCE LIVERMORE NATIONAL LABORATORY			
Advanced Scientific and Computing Research	4,119	-	3,068
Basic Energy Sciences	5,481	4,676	4,676
Biological and Environmental Research	27,539	28,199	36,502
Fusion Energy Sciences	14,510	14,411	13,408
High Energy Physics	1,221	429	429
Nuclear Physics	664	507	700
Science Laboratories Infrastructure	350	250	250
Total Laboratory	53,884	48,472	59,033
LOS ALAMOS NATIONAL LABORATORY			
Advanced Scientific and Computing Research	3,709	5,020	3,570
Basic Energy Sciences	25,089	23,041	23,634
Biological and Environmental Research	23,545	19,245	19,717
Fusion Energy Sciences	7,799	7,308	3,765
High Energy Physics	984	825	825
Nuclear Physics	9,652	9,123	9,104
Science Program Direction	653	670	1,450
Total Laboratory	71,431	65,232	62,065
NATIONAL RENEWABLE ENERGY LABORATORY			
Basic Energy Sciences	5,412	4,562	4,562
Workforce Development for Teachers & Scientists	-	150	200
Total Laboratory	5,412	4,712	4,762
OAK RIDGE NATIONAL LABORATORY			
Advanced Scientific and Computing Research	26,629	10,496	9,819
Basic Energy Sciences	398,845	343,176	257,609
Biological and Environmental Research	58,549	37,495	38,448
Fusion Energy Sciences	19,454	19,258	18,693
High Energy Physics	673	660	660
Nuclear Physics	15,974	16,870	19,330
Safeguards and Security	9,509	7,913	7,913
Science Laboratories Infrastructure	10,745	12,016	10,600
Science Program Direction	60	-	50
Total Laboratory	540,438	447,884	363,122

	FY 2002 Comparable Appropriation	FY 2003 Comparable President's Request	FY 2004 President's Request
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION			
Advanced Scientific and Computing Research	306	99	200
Basic Energy Sciences	2,203	872	872
Biological and Environmental Research	5,850	4,761	4,550
Fusion Energy Sciences	347	808	888
High Energy Physics	80	130	130
Nuclear Physics	607	189	194
Safeguards and Security	1,081	1,254	1,254
Science Program Direction	24	55	100
Workforce Development for Teachers & Scientists	1,377	1,250	1,292
Total Laboratory	11,875	9,418	9,480
PACIFIC NORTHWEST NATIONAL LABORATORY			
Advanced Scientific and Computing Research	4,097	1,003	3,601
Basic Energy Sciences	13,128	11,648	11,648
Biological and Environmental Research	86,047	77,677	81,105
Fusion Energy Sciences	1,415	1,556	1,440
High Energy Physics	54	-	-
Nuclear Physics	20	-	-
Science Laboratories Infrastructure	1,377	4,000	4,120
Science Program Direction	414	465	700
Workforce Development for Teachers & Scientists	635	740	690
Total Laboratory	107,187	97,089	103,304
PRINCETON PLASMA PHYSICS LABORATORY			
Advanced Scientific and Computing Research	400	-	420
Fusion Energy Sciences	69,607	63,576	70,563
High Energy Physics	268	364	364
Safeguards and Security	1,828	1,855	1,855
Science Laboratories Infrastructure	875	545	980
Science Program Direction	-	-	-
Workforce Development for Teachers & Scientists	125	100	150
Total Laboratory	73,103	66,440	74,332

	FY 2002 Comparable Appropriation	FY 2003 Comparable President's Request	FY 2004 President's Request
SANDIA NATIONAL LABORATORY			
Advanced Scientific and Computing Research	5,783	3,889	6,047
Basic Energy Sciences	25,977	25,987	52,949
Biological and Environmental Research	5,334	3,757	5,846
Fusion Energy Sciences	3,178	3,213	2,786
Science Program Direction	155	100	500
Total Laboratory	40,427	36,946	68,128
SAVANNAH RIVER LABORATORY			
Biological and Environmental Research	754	485	239
Fusion Energy Sciences	50	49	45
Total Laboratory	804	534	284
STANFORD LINEAR ACCELERATOR CENTER			
Advanced Scientific and Computing Research	702	234	613
Basic Energy Sciences	34,073	41,716	38,943
Biological and Environmental Research	4,435	5,550	3,675
High Energy Physics	161,587	163,887	169,845
Safeguards and Security	2,150	2,207	2,207
Science Laboratories Infrastructure	400	-	2,000
Workforce Development for Teachers & Scientists	150	150	150
Total Laboratory	203,497	213,744	217,433
THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY			
Advanced Scientific and Computing Research	100	-	-
Biological and Environmental Research	632	500	-
Nuclear Physics	74,761	79,138	82,247
Safeguards and Security	927	972	972
Science Laboratories Infrastructure	-	1,500	3,914
Workforce Development for Teachers & Scientists	50	100	100
Total Laboratory	76,470	82,210	87,233

High Energy Physics

Program Mission

The mission of the High Energy Physics (HEP) program is to understand the universe at a more basic level by investigating the elementary particles that are the fundamental 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 high energy physics and related fields, including particle astrophysics and cosmology, executing a long-range strategy for high energy physics research and technology.

Overview:

The study of high energy physics, also known as particle physics, grew out of nuclear and cosmic ray physics in the 1950's, and measured the properties and interactions of fundamental particles at the highest energies (millions of electron-volts) then available with a relatively new technology, particle accelerators. Today that technology has advanced so that forefront particle accelerators produce exquisitely controlled beams with energies of trillions of electron-volts and intense enough to melt metal. The science has advanced with the technology to study ever-higher energies and very rare phenomena that probe the smallest dimensions we can see and tell us about the very early history of our universe. While the science has revolutionized our understanding of how the universe works, elements of the technology have helped transform other fields of science, medicine, and even everyday life. The science and its impacts will be remembered as one of the highlights of the history of the late 20th century.

But science is not content to rest on its achievements, and high energy physics is poised to make new discoveries that may well remake our world and our understanding of it in the 21st century. The challenge of the HEP program is to exploit those scientific opportunities that appear most promising while maintaining diverse efforts that allow for the unexpected discoveries which are a hallmark of scientific inquiry. The High Energy Physics Advisory Panel (HEPAP), consisting of leading members of the high energy physics community, provides advice to the Department of Energy and the National Science Foundation on a continuing basis regarding the direction and management of the national high energy physics research program. Their 2002 long range planning report conveys the excitement of the questions being addressed by the field today:

Particle physics stands at the threshold of a new era of discovery….experiments in progress and under development offer the potential to… reshape our view of matter and energy, space and time.

The goals outlined in the HEPAP long-range plan are bold and long-term:

During the next twenty years, we will try to understand how the disparate forces and particles of our universe merge together into a single coherent picture….. We will seek new dimensions of space-time, …. And we will seek the mysterious particles and forces that have created indelible imprints on our universe.

The long-range plan outlines the steps to be taken to reach these goals as a "roadmap" for particle physics over the next twenty years. The program described below takes the first steps on that journey.

Major Advances:

The DOE HEP program has indeed been extremely successful. Since the Department of Energy and its predecessors began supporting the research in this field around 1950, our understanding of the fundamental nature of matter has deepened profoundly, generating a stream of Nobel Prizes that are a source of national pride, prestige and scientific leadership:

- 1957 Nobel Prize: Prediction by Columbia University physicists that parity is not conserved in weak interactions
- 1960 Nobel Prize: Invention of the bubble chamber by a physicist at Lawrence Berkeley National Laboratory (LBNL)
- 1968 Nobel Prize: Many discoveries by a physicist at LBNL using the bubble chamber
- 1969 Nobel Prize: Quark model of elementary particle physics proposed by a Cal Tech physicist
- 1976 Nobel Prize: Discovery of the charm quark at Stanford Linear Accelerator Center (SLAC) and Brookhaven National Laboratory (BNL)
- 1980 Nobel Prize: Discovery of charge-parity (CP) violation in K mesons at BNL
- 1988 Nobel Prize: Discovery of the muon neutrino at BNL
- 1990 Nobel Prize: Experimental basis for up and down quarks at SLAC
- 1995 Nobel Prize: Discovery of the electron neutrino by Los Alamos scientists using the Savannah River Plant and discovery of the tau lepton at SLAC

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 smaller constituents called the up quark and the down quark. Four other quarks were also discovered, for a total of six. The last one, and by far the heaviest, called the top quark, was 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 CERN, the European center for HEP research, in 1983. The photon, which carries the electromagnetic force familiar in our everyday lives, has been known since 1905.

The discoveries of the quark structure of matter was 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 the Standard Model, our theory of the fundamental particles and their interactions. The Standard Model includes twelve fundamental constituents of matter called fermions: six quarks and six leptons (familiar examples are the electron and the neutrino). The fermions occur in three families, each containing two quarks and two leptons. Each family has a similar pattern of particle properties, except for mass, which varies widely from one family to the next. All six quarks and three of the leptons were discovered at DOE accelerator laboratories. There is strong evidence that no more families of quarks and leptons exist beyond these three.

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 are subject to all except the strong force. Only two of the quarks are needed to make protons and neutrons. Thus two quarks and just one lepton—the electron—are sufficient to form all the stable matter we observe on Earth.

Another interaction, not yet observed, is also an essential component of the Standard Model. Called the Higgs field, it would be carried by its own special boson, and is believed to be the source of mass for the W and Z bosons, the quarks, and the charged leptons, and hence for all matter.

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 essentially all of them. It explains an amazing array of experimental data. Yet 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 distinct families of fermions (quarks and leptons)? Are these fermions truly the fundamental constituents of matter, or are they made of still smaller particles? Are fermions related somehow to bosons (force particles like the photon, the W boson, and the gluon)? Why do neutrinos change their identities? Do they violate the symmetry of charge exchange/mirror reflection (CP violation), as the quarks do? Can gravity be incorporated into a complete quantum theory of all particles and forces? Are there extra dimensions of space, beyond the three we know? Why is there so little antimatter in the universe, when we expect equal amounts of each were created in the Big Bang? What is the dark matter that provides most of the mass in the universe? What is the dark energy that causes the recently observed acceleration in the expansion of the universe? Is there a consistent cosmology based on a fundamental theory that explains the history and evolution of the universe?

Unique Opportunities:

In FY 2004, the U.S. High Energy Physics (HEP) program is focused on unique opportunities for great discoveries in physics, utilizing the world-class facilities built for this purpose here in the U.S., including the Tevatron facility at the Fermi National Accelerator Laboratory (Fermilab), and the B-factory at the Stanford Linear Accelerator Center (SLAC). The HEP program also makes use of other unique experiments and facilities worldwide to build a diverse and substantial program that has discovery potential in many areas.

The source of mass in elementary particles is one of the principal mysteries of the Standard Model, our theory of the fundamental constituents of matter and their interactions. The theory explains most observations of particles and forces, but not the wide range of particle masses observed, from the nearly massless neutrino to a top quark that is hundreds of billions of times heavier. The Standard Model proposes that an interaction called the Higgs Field permeates the universe and gives mass to elementary particles. Finding evidence of the Higgs Field has been a principal goal of high energy physics for years, with searches underway at accelerator facilities around the world.

The Large Electron-Positron Collider (LEP) at the European Organization for Nuclear Research (CERN) left a tantalizing hint of a Higgs when LEP ceased operations in late 2000. The LEP data suggest a Higgs mass of about 115 GeV, well within reach of the Tevatron. 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 2008. Thus the Tevatron at Fermilab, with substantial upgrades completed in 2001 and further improvements in progress, will have a chance to discover the Higgs before the LHC can get fully underway.

In order to maximize this window of opportunity, 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 underway, interleaved with intensive data runs. If it is successful, by the time LHC produces its first results, the Tevatron should have supplied enough data to find direct evidence of the Higgs if its mass is less than 165 GeV. Tevatron data will also give much more information about the surprisingly heavy top quark discovered there in 1995, and could reveal entirely new classes of particles or even undiscovered space-time dimensions that have been predicted by new theories that seek to complete the unification of fundamental interactions.

At SLAC, the highly successful B-factory and its BaBar detector use electrons colliding at several billion electron volts (GeV) to study a phenomenon known as Charge-Parity (CP) violation in B mesons, which causes an asymmetry in their decays. 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 at Brookhaven National Laboratory using much lighter mesons made of strange quarks. Its accommodation within the current theory has only recently been established through extremely difficult and exquisitely precise measurements at Fermilab and CERN. CP violation has now been observed in the B mesons at SLAC and the big question is whether it will follow theoretical predictions or will indicate a different source of the phenomenon. The B-factory will need a progressive series of upgrades to both the detector and the accelerator in order to be competitive with a similar facility now operating in Japan.

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 perform as expected, be strongly utilized, and eventually be significantly upgraded. Therefore, the FY 2003 budget focused on the utilization and upgrades of these facilities together with support for the research groups (primarily university based) performing the research. 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 the Tevatron and B-factory, there are other unique opportunities in the near-term program. A long baseline neutrino detection experiment, Main Injector Neutrino Oscillation Search (MINOS), is currently being fabricated in Minnesota, and the Neutrinos at the Main Injector (NuMI) beamline construction project at Fermilab will provide a dedicated beam of neutrinos for MINOS. Fermilab has also begun operating a smaller neutrino oscillation experiment called MiniBoone. With NuMI/MINOS and MiniBoone, Fermilab has an opportunity to directly confirm or refute early indications of neutrino oscillations and to make precise mass measurements. Positive results could inaugurate a new era of precision experiments to explore neutrino properties, including the possibility of observing CP violation with neutrinos.

Theory and Accelerator-Based Experiments:

Theoretical research in high energy physics seeks to understand elementary particles and forces. A theorist may pursue established ideas or invent new ones, but each one must be thoroughly explored and developed. A theory is expressed in mathematical form and provides a way to calculate particle properties and interactions, which can be tested experimentally. The theory may also predict new phenomena that can be sought by experimenters. Experimental work tests specific theoretical predictions and also explores for new phenomena not predicted by any theory. 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 more than 100 U.S. universities. In addition, there are participating university scientists supported by the National Science Foundation (NSF), scientists at DOE laboratories (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, they 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 FY 2003, HEP research was also conducted at the Alternating Gradient Synchrotron at BNL. 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 CERN, near Geneva, Switzerland, and those facilities will be even more important to the DOE program in the future. CERN is building the LHC, which will begin commissioning in 2007. Under an international agreement established in 1997, DOE in collaboration with the 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 used telescopes to discover 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 antimatter in space, and the Gamma-ray Large Area Space Telescope (GLAST/LAT) will be placed in earth orbit to study high energy gamma rays from "gamma ray bursters" and other astrophysical sources, using particle physics detection techniques. This class of astrophysical phenomena is particularly interesting because it indicates that out in space there are particle acceleration mechanisms (and hence forces) far greater than any encountered here on earth. The scientific topics studied will include those of interest to both particle physicists and cosmologists, such as the "dark matter" responsible for large-scale galactic structures: new fundamental particles are a popular candidate for such dark matter.

The proposed SuperNova Acceleration Probe (SNAP) would put an advanced imaging telescope in space to follow-up on the discovery of the accelerating universe with a detailed study of the Dark

Energy that is postulated to be responsible for pushing the universe apart. This mysterious Dark Energy makes up about two-thirds of the energy budget of the Universe, and does not fit into our current model of fundamental matter and forces. Measurements of the nature of Dark Energy will lead to an understanding of the history of the expansion of the Universe, from about 10 billion years ago until the present.

Technology Development:

High energy physics research deals with very high particle energies and very small distance scales. Experimenters must make precision measurements of phenomena buried in a background of noise or search for very rare processes. Such research demands particle beams of great intensities and detectors with the sensitivity to see the rare events and the selectivity to pull these out of background noise. The HEP program supports advanced technology research and development aimed at developing higher energy accelerators and more sensitive and selective detectors.

It is essential to accumulate, store, process, and transmit to hundreds of researchers worldwide the increasingly large data sets produced by modern experiments. Some theoretical problems also require massive computing resources. For example, the theory of strong interactions (called "Quantum Chromodynamics (QCD)") can be solved to high precision only using advanced, high-performance computers. Development of suitable computing resources for experiment and theory is supported by the program and additional resources are provided through the *Scientific Discovery through Advanced Computing* (SciDAC) program (see below).

Operating in these extreme domains requires substantial time and expense to design, build, maintain, operate, and upgrade the 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 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 for their research. Fortuitously, it is from this technology R&D that many of the spin-offs to other sciences and the marketplace originate. See "Benefits to Other Sciences and Citizens" below for examples.

The technology R&D program supported by the DOE High Energy Physics program includes studies of the fundamental science principles underlying the design and operation of accelerators, storage rings, and detectors that are the principal tools of the research, the invention and reduction to practice of new devices and technology, and the development of designs for devices essential to the research capabilities of the future.

The research in accelerator science includes studies in nonlinear dynamics of particle beam optics, applications of chaos theory to the behavior of space charge dominated particle beams, new computational techniques, and computer modeling of accelerator storage ring and detector systems. An essential part of the research is the search for new accelerator concepts and methods. Excellent progress has been made in the use of lasers and plasmas in the acceleration of electrons and positrons (anti-electrons) and in the exploration of alternate radio frequency acceleration techniques. A significant R&D effort is development of superconducting wire and cable for use in superconducting magnets. The development of niobium tin and niobium aluminum as well as the application to the newer high temperature superconductors is done in collaboration with U.S. industry through direct grants and the

Small Business Innovation Research (SBIR) program. This work together with development of new magnet geometries for the generation of very magnetic fields sustains and advances this essential core competency of the technology R&D used in high energy physics.

The Department is continuing research and development directed toward accelerator facilities that will be needed for the future. The 2002 HEPAP long range planning report recommends “that the highest priority of the U.S. program be a high energy, high-luminosity, electron-positron linear collider.” Work is directed toward achieving a center-of-mass energy for a Linear Collider (LC) in the TeV range 500 to 1000 GeV, expandable to 1.5 TeV. (A GeV is one billion electron volts of energy). The LC 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 LC may well be international, and research and development on linear colliders is also underway in other countries, primarily Germany and Japan.

For energies well beyond the LHC, a next-generation, very high energy hadron collider is a natural candidate for a possible future accelerator with great discovery potential. Its research program may include investigations of new particles, extra dimensions, quantum gravity, or phenomena not even thought of today. Such an accelerator might have a collision energy greater than 100 TeV, much higher than that of the LHC (14 TeV). Work is underway at several laboratories and universities toward designing magnets that could make such a hadron collider affordable. This basic research into production-quality high-field magnets is a long-term effort that may pay dividends to other fields of science and technology as well.

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 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 large teams. Many of them go into careers in high-tech industries, contributing to our country's economic strength.

How We Work:

The High Energy Physics program coordinates and funds high energy physics research. The program is responsible for planning and prioritizing all aspects of supported research, conducting ongoing assessments to ensure a comprehensive and balanced portfolio, regularly seeking advice from stakeholders, supporting core university and national laboratory programs, and maintaining a strong infrastructure to support high energy physics research.

Advisory and Consultative Activities:

To ensure that resources are allocated to the most scientifically promising experiments, the Department of Energy and its national laboratories actively seek external input using a variety of advisory bodies.

The ***High Energy Physics Advisory Panel (HEPAP)*** provides advice to the Department of Energy and the National Science Foundation on a continuing basis regarding the direction and management of the national high energy physics research program. In FY 2002, the DOE HEP program provided about 90% of the federal support for high energy physics research in the nation. The National Science Foundation (NSF) provided most of the remaining support. HEPAP regularly meets to advise the agencies on their research programs, assess their scientific productivity, and evaluate the scientific case for new facilities.

Laboratory directors seek advice from ***Program Advisory Committees (PACs)*** to determine the allocation of a scarce scientific resource—the available beam time. Committee members, mostly external to the laboratory, are appointed by the director. PACs review research proposals requesting time at the facilities and technical resources; judging each proposal's scientific merit, technical feasibility, and manpower requirements and recommending whether the proposal should be approved, conditionally approved, deferred, or rejected. Non-accelerator research proposals to DOE and NSF are reviewed by a special advisory committee called SAGENAP (Scientific Assessment Group for Experiments in Non-Accelerator Physics).

Review and Oversight:

The High Energy Physics program provides review and oversight for its research portfolio. All ***university*** research proposals are subjected to an intensive and multistage review process to ensure high quality research and an appropriate mix of experiments in the national program. A university proposal to perform an experiment at a laboratory facility is reviewed by the laboratory PAC as described above. Its proposal to DOE for support is peer-reviewed by a group of external technical experts. Once a university group is funded, regular site visits and peer reviews are performed to ensure that the quality of the research is maintained.

The program also conducts annual in-depth reviews of the high energy physics program at each ***laboratory***, using a panel of external technical experts. These on-site reviews examine the institutional health of the laboratory, its high energy physics research program, and, as appropriate, the state of its user facilities. The results are used in setting priorities both at the laboratory and within the national program. HEPAP meets once a year at one of the major high energy physics laboratories and devotes one-third of its time to a review of that laboratory's program. Findings and recommendations are transmitted to DOE. In addition, the HEP program participates in the annual SC Institutional Reviews for each of its laboratories and semi-annual reviews of each of its ongoing construction projects conducted by the Construction Management Support Division in the Office of Science.

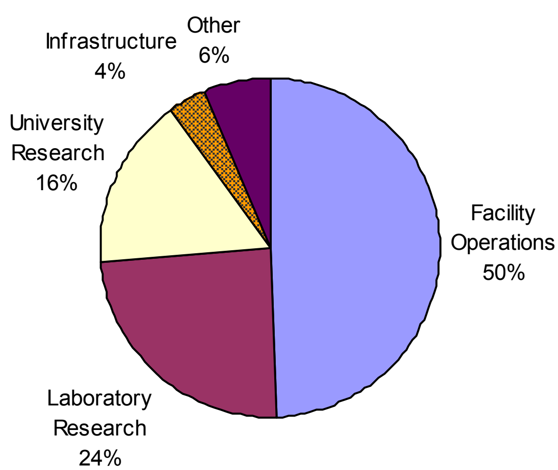
Planning and Priority Setting:

One of the most important functions of HEPAP is development of long-range plans that express community-wide priorities for future research. The most recent such plan was submitted in January 2002 and presented a roadmap for the field, laying out the physics opportunities the planning subpanel could envision as possibilities for the next twenty years. As part of this roadmap, the panel recommended that the highest priority of the U.S. program be a high energy, high-luminosity electron-positron linear collider to be built as a fully international effort. A Linear Collider Steering Group has been formed, comprised of eminent members of the field, to coordinate U.S. efforts toward a linear collider. HEPAP further recommended vigorous long-term R&D toward future accelerators as a high priority.

How We Spend Our Budget:

The High Energy Physics budget has five major components by function. About 50% of the program funding was provided to HEP laboratories (Fermilab and SLAC) for facility operations; a total of 24% was provided to laboratories, including multipurpose laboratories, in support of their HEP research activities; 16% was provided for university-based research; 4% for infrastructure improvements (construction plus GPP and GPE); and 6% for other activities (including SBIR and STTR). The FY 2004 budget request is focused on facility operations and upgrades at Fermilab and SLAC to advance research with the CDF and D-Zero detectors at the Tevatron and the BaBar detector at the B-factory.

HIGH ENERGY PHYSICS
FY 2004



Research:

The DOE High Energy Physics program supports approximately 2450 researchers and students at over 100 U.S. universities located in 36 states, Washington, D.C., and Puerto Rico, and 8 laboratories located in 5 states. These physicists conceive and carry out the high energy physics research program. Funding for university and laboratory research is held essentially flat compared to FY 2003 in order to support high-priority facility operations. National laboratory research scientists work together with the experimental collaborations to collect and analyze data as well as support and maintain the detectors. The laboratories provide state-of-the-art resources for detector and accelerator R&D for future upgrades and new facilities. The division of support between national laboratories and universities is adjusted to maximize productivity.

- ***University Research:*** University researchers play a critical role in the nation's research effort and in the training of graduate students. During FY 2002, the DOE High Energy Physics program supported approximately two-thirds of the nation's university researchers and graduate students engaged in fundamental high energy physics research. Typically, about 120 Ph.D. degrees are granted annually to students for research supported by the program.

  The university grants program is proposal driven, and funds the best and brightest of those ideas submitted in response to grant solicitation notices. Proposals are reviewed by external scientific peers and competitively awarded according to the guidelines published in Office of Science Regulation 10 CFR 605. Thereafter, the research is monitored to ensure quality of research is maintained (see Review and Oversight, above).

- ***National Laboratory Research:*** The High Energy Physics program supports research groups at the Fermi, Lawrence Berkeley, Lawrence Livermore, Argonne, Brookhaven, and Los Alamos National Laboratories, Princeton Plasma Physics Laboratory, and the Stanford Linear Accelerator Center. The directions of laboratory research programs are driven by the needs of the Department and are tailored to the major scientific facilities at the laboratories. Laboratory researchers collaborate with academic users of the facilities and are important for developing and maintaining the large experimental detectors and computing facilities for data analysis.

  The High Energy Physics program funds field work proposals from the national laboratories. Performance of the laboratory groups is reviewed annually by program staff assisted by an external panel of technical experts (see Review and Oversight, above), to examine the quality of their research and identify needed changes, corrective actions, or redirection of effort. Individual laboratory groups have special capabilities or access to laboratory resources that can be profitably utilized in the development of the scientific program.

Program Strategic Performance Goals

SC1-1: Manage a program that provides world-class, peer-reviewed research results in the scientific disciplines encompassed by the High Energy Physics mission areas, cognizant of the needs of DOE and of the wider scientific community. (Proton Accelerator-Based Physics, Electron Accelerator-Based Physics, Non-Accelerator Physics, Theoretical Physics and Advanced Technology subprograms)

Performance Indicators

Validation of results by merit review with external peer evaluation; Validation of program directions by the High Energy Physics Advisory Panel.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
		At least 80% of all new research projects will be peer reviewed and deemed excellent (of highest quality) and relevant, and annually 30% of all ongoing projects will be subject to peer review with merit evaluation. (SC1-1-1) Respond to priorities and recommendations for the DOE High Energy Physics program in the 2002 High Energy Physics Advisory Panel Long Range Plan: • support R&D for a high-energy, high-luminosity electron-positron linear collider as the next major facility in the field, and prepare the U.S. to bid to host the facility; • respond to advice from the Particle Physics Project Prioritization Panel concerning possible future HEP projects. (SC1-1-2)

SC7-1: 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. (Proton Accelerator-Based Physics subprogram and Electron Accelerator-Based Physics subprogram).

Performance Indicator

Percent on time/on budget; Percent unscheduled downtime; Validation of results by merit review with external peer evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Complete and deliver A Toroidal LHC ApparatuS (ATLAS) detector barrel cryostat and feedthroughs to CERN. *[Met goal]*		Complete installation of CMS calorimeter in surface building.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Complete prototype Large Hadron Collider quadrupole and dipole magnets. *[Met goal]*		Begin vertical integration tests of CMS subsystems. Complete production of Large Hadron Collider beam separation dipole magnets.
The completion targets for the U.S. portion of the Large Hadron Collider project are: CMS 77% ATLAS 72% Accelerator 85% *[Mixed Results]*(SC7-1-1)	The completion targets for the U.S. portion of the Large Hadron Collider project are: CMS 78% ATLAS 78% Accelerator 86% (SC7-1-1)	The completion targets for the U.S. portion of the Large Hadron Collider project are: CMS 84% ATLAS 83% Accelerator 90% (SC7-1-1)
	Conduct, using outside experts, a review (1) of the operations and performance of the HEP–supported accelerator facility at Fermilab (Tevatron) to identify opportunities to optimize efficiency and performance. (SC7-1-2)	Conduct, using outside experts, a review (1) of the operations and performance of the HEP–supported accelerator facility at SLAC (B-factory) to identify opportunities to optimize efficiency and performance. (SC7-1-2)
Maintain and operate HEP facilities such that unscheduled downtime is less than 20% of the total scheduled operating time. *[Met goal]* (SC7-1-3)	Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time. (SC7-1-3)	Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time. (SC7-1-3)

Program Assessment Rating Tool (PART) Assessment

The High Energy Physics program participated in the PART review conducted by the Office of Management and Budget. The program scored highly in the Purpose and Management sections primarily as the result of a well-defined mission and merit-based reviews for awarding contracts and grants. Lower scores in Planning and Results/Accountability were attributed primarily to the program's lack of adequate long-term and annual performance measures; however, it was noted that the program has made significant strides toward developing such measures despite the problems inherent in measuring and predicting scientific progress. Further contributing to the lower Results score was the fact that two construction projects were under-performing or over budget/schedule, partly because the program is undertaking several high-risk projects simultaneously. Reviews of the program are conducted by HEPAP, and also the Division of High Energy Physics conducts annual reviews, using independent consultants, of the HEP programs at its five laboratories. However, it was called out that the program does not currently have regular reviews of its research portfolio and processes by ad hoc panels of outside technical experts.

As a result of the above findings, the High Energy Physics program will take the following actions in FY 2004. The program will work further to reform its performance measures and goals while being sensitive to the problems that basic research programs face in attempting to predict future scientific progress. Also, the FY 2004 budget focuses resources on addressing construction and upgrade problems at Fermilab while simultaneously operating the laboratory at 82 percent of maximum capacity (compared to 87 percent in FY 2003 and 78 percent in FY 2002). The program has formed a committee, called the Particle Physics Project Prioritization Panel (P5), to prioritize its medium and large ($50-600M TEC) construction projects and MIEs within the program that have not yet reached the full construction phase. The first meeting of P5 is scheduled for late January 2003. In addition, the program will institute a process, by September 2003, for reviewing its research portfolio by a formal committee of visitors.

Significant Program Shifts

- A number of planned upgrades to the Tevatron and the B-factory 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.
- The operation of the Tevatron collider complex has been disappointingly slow in achieving the desired beam intensities in the early phase (FY 2001-2002) of its major datataking run ("Run II"), perhaps diminishing some of the opportunities described above. Fermilab has assigned its highest priority to rectifying this situation. Internal resources have been redirected to solve the Tevatron performance issues, slowing progress on longer-term accelerator R&D projects that are not essential to the near-term goal of maximizing the Tevatron's ability to discover new physics.
- The extra resources needed to meet Tevatron Run II luminosity goals are mostly the efforts of accelerator physicists at Fermilab, and are not incurring "extra" costs to the program. Costs for materials and hardware needed to upgrade the Tevatron had already been planned and budgeted as noted above. A few SLAC, LBNL and BNL accelerator physicists with specialized expertise relevant to Run II problems have been recruited to help as well.
- DOE has established an exciting and expanding partnership with NASA in the area of Particle Astrophysics and Cosmology. The Alpha Magnetic Spectrometer (AMS) and Gamma-ray Large Area Space Telescope (GLAST/LAT) experiments have been underway for some time, and there is an exciting new proposal for an interagency experiment – the SuperNova Acceleration Probe (SNAP) -- to explore the nature of the recently-discovered "dark energy" which appears to be causing an accelerating expansion of the universe. These experiments, and others that may be proposed, will provide important new information about the birth, evolution and ultimate fate 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/LAT experiments, which are joint DOE-NASA projects, have received NASA mission approval.
- The Neutrinos at the Main Injector (NuMI) project has overcome 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.
- The HEP budget structure has changed significantly to realign the subprograms, allowing the budget to be presented more clearly in terms of the major physics thrusts in the overall program.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) activity is a set of coordinated investments across all Office of Science mission areas with the goal to achieve breakthrough scientific advances through computer simulation that were impossible using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. By exploiting advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-discipline collaboration among the scientific disciplines, computer scientists and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can fully exploit terascale computing and networking resources. The program will bring simulation to a parity level with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate prediction, plasma physics, particle physics, astrophysics and computational chemistry.

Scientific Facilities Utilization

The High Energy Physics request supports 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). These facilities provided a total of 74 weeks of beam time in FY 2002 for a research community of about 2,200 U.S. scientists in HEP and related fields. A comparable number of users come from foreign countries, testifying to the fact that these are unique, world-leading experimental facilities. The FY 2004 President's Budget Request will support facility operations that will provide ~75 weeks of beams for research. This plan will maintain the FY 2003 level at SLAC and a slight decrease at Fermilab associated with required shutdown for facility modification and upgrades.

High Energy Physics will maintain and operate its major scientific user facilities so that the unscheduled operational downtime will be kept below 20%, on average, of total scheduled operating time.

	Estimated maximum utilization	FY 2002	FY 2003	FY 2004 Request
Tevatron Collider at Fermilab				
Maximum hours = 5400				
Scheduled running weeks	45	39	39	36
Unscheduled Downtime		18%	<20%	<20%
Number of Users = 2160				
B-factory at SLAC				
Maximum hours = 5850				
Scheduled running weeks	45	35	39	39
Unscheduled Downtime		14%	<20%	<20%
Number of Users = 1100				

In FY 2003, the Alternating Gradient Synchrotron at Brookhaven National Laboratory ceased its program of High Energy Physics research.

High Energy Physics will meet the cost and schedule milestones for construction of facilities and Major Items of Equipment (MIE) within their contingencies allocated in the baseline estimates.

	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004 Request
Major milestones completed or committed to	Completed Central Detector Facility (CDF) Run II upgrade at Fermilab Completed Large Hadron Collider accelerator dipole model magnet program	Completed D-Zero Run II upgrade at Fermilab Completed U.S. Compact Muon Solenoid (CMS) hadron calorimeter absorber and delivered to CERN	Completed construction of U.S. A Toroidal LHC Apparatus (ATLAS) tile calorimeter sub-modules Completed fabrication of first half of Main Injector Neutrino Oscillation (MINOS) experiment	Complete Neutrinos at the Main Injector (NuMI) excavation Complete AntiMatter in Space (AMS) upgrade Complete first inner triplet quadrupole magnet for LHC accelerator	Complete NuMI civil construction Complete U.S. ATLAS Transition radiation tracker module production Complete U.S. CMS Hadron calorimeter readout test Complete Pierre Auger project construction

Construction and Infrastructure:

Funding for construction and capital equipment is down significantly compared to FY 2003 as several construction projects are ramping down, and R&D activities directed at NLC are kept constant. The High Energy Physics program as part of its responsibilities as the landlord for Fermilab, SLAC, and Lawrence Berkeley National Laboratory provides funding for general plant projects (GPP) and general purpose equipment (GPE).

Workforce Development

The High Energy Physics program supports development of the R&D workforce through support of graduate students working toward a doctoral degree and post-doctoral 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), national security, space exploration, software and computing, telecommunications, and many more fields.

About 1,200 post-doctoral associates and graduate students supported by the High Energy Physics program in FY 2002 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 accelerator facilities (~90%) supported by the DOE, NSF, and foreign countries as well as participating in non-accelerator research (~10%).

Details of the High Energy physics manpower are given below. These numbers include people employed by universities and laboratories. The University grants include Physics Research and Accelerator Technology grants. In FY 2001, there were 140 University grants with an average funding of $850,000 per year. Most of these are multi-task grants with an average of three tasks. The duration of the grants is three years. The number of laboratory groups is an estimate of the number of distinct HEP research groups (experiment, theory, accelerator R&D) at the laboratories, which is a collection of single and multi-task efforts.

Human Resources (Full-Time Equivalent) in High Energy Physics

at Laboratories and Universities, DOE supported

	FY 2001	FY 2002	FY 2003 est.	FY 2004 est.
University Grants	145	140	140	140
Lab Groups	51	51	50	50
Ph.D.'s with permanent positions	1265	1255	1255	1255
Postdoctoral Associates	575	565	565	565
Graduate Students	615	605	610	610
# Ph.D.'s awarded	125	120	120	120

Funding Profile

(dollars in thousands)

	FY 2002 Comparable Appropriation	FY 2003 Request	FY 2004 Request	$ Change	% Change
High Energy Physics					
Proton Accelerator-Based Physics	388,117	387,886	399,494	+11,608	+3.0%
Electron Accelerator-Based Physics	148,232	150,148	159,486	+9,338	+6.2%
Non-Accelerator Physics	39,115	37,420	43,000	+5,580	+14.9%
Theoretical Physics	43,005	42,490	42,256	-234	-0.6%
Advanced Technology R&D	67,514	86,953	81,242	-5,711	-6.6%
Subtotal, High Energy Physics	685,983	704,897	725,478	+20,581	+2.9%
Construction	11,400	20,093	12,500	-7,593	-37.8%
Total, High Energy Physics	697,383[ab]	724,990	737,978	+12,988	+1.8%

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 $14,521,000 which was transferred to the SBIR program and $871,000 which was transferred to the STTR program.

[b] Excludes $395,000 for the FY 2002 rescission contained in Section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to terrorist attacks on the United States.

Funding by Site [a]

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	984	825	825	0	0.0%
Chicago Operations Office					
Argonne National Laboratory	9,849	10,293	10,043	-250	-2.4%
Brookhaven National Laboratory	39,117	23,319	21,161	-2,158	-9.2%
Fermi National Accelerator Laboratory	306,782	313,200	304,663	-8,537	-2.7%
Princeton Plasma Physics Laboratory	268	364	364	0	0.0%
Chicago Operations Office	83,465	74,527	72,804	-1,723	-2.3%
Total, Chicago Operations Office	439,481	421,703	409,035	-12,668	-3.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	43,284	32,530	39,183	+6,653	+20.4%
Lawrence Livermore National Laboratory	1,221	429	429	0	0.0%
Stanford Linear Accelerator Center	161,587	163,887	169,845	+5,958	+3.6%
Oakland Operations Office	38,152	44,000	36,228	-7,772	-17.7%
Total, Oakland Operations Office	244,244	240,846	245,685	+4,839	+2.0%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education	80	130	130	0	0.0%
Oak Ridge National Laboratory	673	660	660	0	0.0%
Total, Oak Ridge Operations Office	753	790	790	0	0.0%
Richland Operations Office					
Pacific Northwest National Laboratory	54	0	0	0	0.0%
Washington Headquarters	11,867	60,826	81,643	+20,817	+34.2%
Total, High Energy Physics	697,383[bc]	724,990	737,978	+12,988	+1.8%

[a] On December 20, 2002, the National Nuclear Security Administration (NNSA) disestablished the Albuquerque, Oakland, and Nevada Operations Offices, renamed existing area offices as site offices, established a new Nevada Site Office, and established a single NNSA Service Center to be located in Albuquerque. Other aspects of the NNSA organizational changes will be phased in and consolidation of the Service Center in Albuquerque will be completed by September 30, 2004. For budget display purposes, DOE is displaying non-NNSA budgets by site in the traditional pre-NNSA organizational format.

[b] Excludes $14,521,000 which was transferred to the SBIR program and $871,000 which was transferred to the STTR program.

[c] Excludes $395,000 for the FY 2002 rescission contained in Section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to terrorist attacks on the United States.

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 in the past 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 was 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 two large multi-purpose detectors, 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 commissioning in 2007. With the shutdown of the LEP machine at CERN in Switzerland in 2000, the Tevatron became the only operating particle accelerator at the energy frontier. The Tevatron complex also includes the Booster and the Main Injector, pre-accelerators 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. The Booster is used to accelerate low-energy protons, and a small part of the beam that is not used for Tevatron collider operations is provided to produce neutrinos for short-baseline oscillation experiments. 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 advanced 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.

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 B-factory and its detector, BaBar, and a small program of fixed target experiments. The B-factory, a high energy electron-positron collider, was constructed to support a search for and high-precision 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.

All Other Sites

The High Energy Physics program supports about 260 research groups at more than 100 colleges and universities located in 36 states, Washington, D.C., and Puerto Rico. The strength and effectiveness of the university-based program is critically important to the success of the program as a whole. 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 (NIST), Naval Research Laboratory (NRL), the Smithsonian Institution), and a few small companies. Through its participation in the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, the DOE HEP program also supports advanced technology R&D at over 70 small businesses located throughout the U.S.

Facilities Summary

Fermilab

In FY 2004, Fermilab plans 36 weeks of running to achieve a performance goal of 400 pb-1 of data delivered to the major Tevatron experiments. Approximately 850 people are involved in day-to-day Tevatron operations, which include operation of the Tevatron accelerator complex and the CDF and D-Zero detectors. This is one of the major data collection periods for the experiments searching for the Higgs and other signals of new physics at the world's energy frontier facility as described in more detail in the Unique Opportunities section above.

Fully achieving the physics goals of the Tevatron program over the next five years requires a series of performance enhancements to the accelerator and the CDF and D-Zero detectors. These efforts are proceeding in parallel with current Tevatron operations and research and are more fully described in the Detailed Justification sections that follow.

Tevatron operations also include the running of the Tevatron complex in fixed target mode in parallel with Tevatron collider operation. This will be for the physics data taking of the MiniBooNE experiment (8 GeV protons extracted from Booster ring) and for test beam runs (120 GeV protons extracted from Main Injector). In FY 2004, the MiniBooNE experiment will be operating its beam line and detector to collect data. Test beam runs will be scheduled as needed. These functions are non-interfering with the high-priority Tevatron collider operations.

SLAC

In FY 2004, SLAC plans 39 weeks of running to achieve a performance goal of 50 fb^{-1} of data delivered to the BaBar experiment. Approximately 450 people are involved in day-to-day B-factory and BaBar operations. This will be the priority research program at SLAC in FY 2004. It is anticipated that the collected data will exceed the total collected in FY 2003, providing a significant enhancement to the BaBar dataset for precision studies of CP violation in the B-meson system, as described above.

Fully achieving the physics goals of the B-factory program over the next five years requires a series of performance enhancements to the accelerator and the BaBar detectors. 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. These efforts are proceeding in parallel with current B-factory operations and research and are more fully described in the Detailed Justification sections that follow.

AGS

Operations at BNL for HEP experiments using the AGS facility were terminated in FY 2003.

HEP facilities operations funding and running weeks are summarized in the table below for the Tevatron, B-factory and Alternating Gradient Synchrotron (AGS):

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Tevatron Operations	191,958	181,638	190,955
Tevatron Improvements[a]	49,677	51,589	57,240
Total, Tevatron	241,635	233,227	248,195
Running Weeks	39	39	36
B-factory Operations	97,334	97,275	104,225
B-factory Improvements[b]	20,595	19,810	21,618
Total, B-factory.	117,929	117,085	125,843
Running Weeks	35	39	39
AGS Operations	5,917	0	0
AGS Support	95	0	0
Total, AGS	6,012	0	0
Running Weeks	18	0	0

[a] Includes Run IIb CDF and D-Zero detectors and Tevatron Accelerator, R&D on possible future accelerator improvements, the MINOS detector and general improvements to the laboratory infrastructure. For details see the Detailed Program Justification to follow.

[b] Includes upgrades to the BaBar detector and B-factory accelerator, and general improvements to the laboratory infrastructure. For details see the Detailed Program Justification to follow.

Proton Accelerator-Based Physics

Mission Supporting Goals and Measures

The Proton Accelerator-Based Physics subprogram exploits U.S. leadership at the energy frontier by conducting experimental research that will determine whether the Standard Model correctly predicts the mechanism that generates mass for all fundamental particles, or provide clear evidence for physics beyond the Standard Model. The Proton Accelerator subprogram also includes support for the facilities and research groups to perform decisive controlled measurements of basic neutrino properties, including neutrino oscillations that will provide important clues and constraints to the theory of matter and energy beyond the Standard Model.

Introduction

Proton accelerators are capable of producing the highest-energy particle beams made by man, and by colliding proton beams into targets, large samples of other particles like antiprotons, *K* mesons, muons, and neutrinos can be produced and formed into beams for experiments. The proton accelerator subprogram uses both of these aspects of proton accelerators.

The Tevatron at Fermilab is the highest-energy particle accelerator in the world. It produces collisions of 1 TeV protons with 1 TeV antiprotons. Because of the high energy of the collisions and the fact that the particles interact via three different interactions, the collisions can be used to study a wide variety of physics topics. All of the six different types of quarks are produced in these interactions with the heaviest, the top and bottom quarks, being of the most interest. Most of the force carrying particles are also directly produced, and if the masses of predicte – but as yet unobserved – particles, like the Higgs boson or supersymmetric particles are low enough, they will also be produced at the Tevatron. Two large general-purpose detectors, CDF and D-Zero, have been built to mine this rich lode of physics.

The Higgs boson is a crucial missing piece of the puzzle underlying the interactions of quarks and leptons. While the Standard Model predicts its existence, the mass of the Higgs boson is not known. Very general theoretical arguments point to the conclusion that collisions of quarks or leptons with energies in the ballpark of 1 TeV are likely to produce the Higgs. The current physics program at the Proton Accelerator-Based facilities will be focused on the unique opportunity for the discovery of the Higgs boson, which has been a principal goal of high energy physics for years and may explain the source of mass for all elementary particles. A unique opportunity exists at Fermilab to search for a Higgs boson. This opportunity results from recent DOE investments in the construction of the Fermilab Main Injector and the upgrades of the collider detectors. Other areas with great discovery potential include the search for supersymmetric particles, the hypothetical heavier "twins" of all known elementary particles, and the search for evidence of extra space-time dimensions that are hidden in everyday life. Either of these discoveries, or any of a number of other possibilities, would be key elements in understanding the physics beyond the Standard Model. These energy frontier programs will be carried out at the Tevatron at Fermilab, followed by the LHC program at CERN over the next decade. In parallel, there will be other wide varieties of very interesting physics to pursue. The number of top quarks – the most massive fundamental particle known – discovered and studied during the previous Tevatron collider run was less than 100. The new run will produce an order of magnitude more top quarks, which will allow a serious study of its properties. A variety of B meson studies will be done, including independent confirmation of CP violation, which has been observed at the B-factories at

SLAC and in Japan. Other processes, inaccessible to the B-factories, can also be measured. These measurements provide vital pieces of the theoretical framework used to explain CP violation, and an explanation of CP violation is necessary to understand why matter (and not antimatter) is what makes up the universe we live in. A precision measurement of mass of the W boson and detailed studies of the charm quarks will also be carried out.

Neutrino physics presents today one of the most promising avenues to probe for extensions of the Standard Model. *A priori*, no fundamental reason exists why neutrinos should have zero mass or why there should be no mixing between different neutrino species. In the past few years, a number of interesting new results have been reported by several different experiments, including the Liquid Scintillation Neutrino Detector (LSND) experiment at Los Alamos, the Super-K and KamLAND experiments in Japan and the Sudbury Neutrino Observatory experiment in Canada. These experiments provide compelling evidence that neutrinos do have mass and that they do change their identities (the different neutrino species "mix") as they travel. Unfortunately, the neutrinos used by these experiments have a wide range of energies and are produced in insufficient numbers to precisely measure their oscillation parameters. One of the unique opportunities in the Proton Accelerator subprogram is exploring and making precision measurements of the neutrinos, which will be generated by using dedicated proton beam facilities in a well-controlled environment (e.g., the Neutrinos at the Main Injector or NuMI project at Fermilab).

The major activities under the Proton Accelerator subprogram are the broad research programs using the CDF and D-Zero detectors at the Tevatron at Fermilab; the neutrino research program using the NuMI/MINOS and MiniBooNE facilities at Fermilab and at the Soudan Mine site in Minnesota; the LHC program, and maintenance and operation of these facilities. The Tevatron collider programs will determine whether the Standard Model accurately predicts the mechanism that breaks the symmetry between natural forces and generates mass for all fundamental particles or whether an alternate theory is required. The NuMI/MINOS and MiniBooNE programs will perform decisive controlled measurements of fundamental neutrino properties, including neutrino oscillations, which will provide important clues and constraints to the theory of matter and energy beyond the Standard Model. The LHC program will insure that the U.S. high energy physics research program will be one of the key players at the next energy frontier. There are much smaller specialized efforts involving the HERA accelerator machine at DESY in Germany, and the KEK proton accelerator in Japan.

Research and Facilities

The Research category in the Proton Accelerator subprogram supports the university and laboratory based scientists performing experimental research at proton accelerator facilities in the U.S. and abroad. Experimental research activities are collaborative efforts by research groups from ANL, BNL, Fermilab, LBNL, LANL, LLNL, and about 60 colleges and universities and include: planning, design, fabrication and installation of experiments and associated computing infrastructure; preparation for experimental operations and conduct of experiments; analysis and interpretation of data; and publication of results. These research programs are carried out at various facilities where the accelerators and detectors are located. The university program also includes a small amount of funds at national laboratories (so-called "university service accounts") to allow university groups to perform specific tasks connected with the experimental research program, such as purchasing needed equipment from laboratory stores.

The Facilities category in the Proton Accelerator subprogram supports the maintenance and operations of, and technical improvements to, proton accelerator facilities in the U.S. In addition, this category supports the U.S. share of operations, software and computing infrastructure, and directed technical

R&D for international proton accelerator facilities such as the LHC at CERN. Facilities activities include: installation, commissioning, maintenance and operations of accelerators and experiments; providing computing hardware and software infrastructure to support the experiments and the accelerators, and provide platforms for data analysis; and directed R&D for accelerator and detector enhancements and performance improvements. Since physicists are often involved in these activities as well as research activities, some are partially supported by both categories of funding where appropriate.

The proton accelerator facilities support personnel are based primarily at ANL, BNL, Fermilab, and LBNL, working together with experimental groups from various universities and foreign institutions.

Highlights

Recent accomplishments include:

- The CDF and D-Zero detectors at Fermilab have been largely rebuilt for Run II of the Tevatron collider. The collaborations have announced initial results based on first collisions observed in 2001. These detectors have much greater sensitivity than before and will search for the Higgs or other new physics, and will make numerous precision measurements.
- The Tevatron completed commissioning of the new Main Injector, and the two upgraded detectors (CDF and D-Zero) were brought into operation in FY 2001.
- A new accelerator-based neutrino program in the U.S. was launched in 2002 when the MiniBooNE detector at Fermilab began taking data using a low-energy proton beam to confirm or refute hints of neutrino oscillations discovered at Los Alamos in the LSND experiment.
- 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 after the LHC begins commissioning in FY 2007. A parallel effort to test, commission, and eventually operate the U.S.-supplied systems that are part of the LHC detectors has also been initiated, and significant pre-operations activities will begin in FY 2004.
- 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 did not quite agree with the Standard Model, suggesting perhaps new physics. However, a mistake in the theoretical calculation was found, bringing theory and experiment into much closer agreement. The measurement precision has recently improved by a factor of two due to analysis of additional data, but the comparison with theory is still cloudy due to theoretical uncertainties. Work continues on both fronts: analyzing more data and reconciling theoretical questions.

The major planned research efforts in FY 2004 are:

- 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 physics issues to be addressed include searches for the Higgs boson, supersymmetry or other new phenomena; B meson studies including CP violation; and precision measurements of the top quark and the W boson properties.

- 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. The physics issues to be addressed include searches for the Higgs boson, supersymmetry or other new phenomena; B meson studies including CP violation; and precision measurements of the top quark and the W boson properties.

- THE RESEARCH PROGRAM USING THE MINIBOONE AND NUMI/MINOS FACILITIES AT FERMILAB AND THE SOUDAN MINE. These research programs are being carried out by a collaboration including scientists from Fermilab, ANL, BNL, LANL, LLNL, 26 U.S. universities, and institutions in 10 foreign countries. The major efforts in FY 2004 will be data taking and analysis (MiniBooNE) and developing computing and data analysis tools (MINOS).

- PLANNING AND PREPARATION FOR THE U.S. PORTION OF THE RESEARCH PROGRAM OF THE LHC. A major effort in FY 2004 will continue to be the design and implementation of the U.S. data handling and computing capabilities needed for full participation in the LHC research program. Pre-operations of U.S.-supplied detectors for LHC experiments will begin at CERN.

The major planned facilities efforts in FY 2004 are:

- OPERATIONS OF THE TEVATRON AT FERMILAB. Fermilab plans 36 weeks of running to achieve a performance goal of 400 pb-1 of data delivered to the major Tevatron experiments. Approximately 850 people are involved in day-to-day Tevatron operations, which include operation of the Tevatron accelerator complex and the CDF and D-Zero detectors.

- PLANNING AND PREPARATION FOR TEVATRON/CDF/D-ZERO PERFORMANCE ENHANCEMENTS. Fully achieving the physics goals of the Tevatron program over the next five years requires a series of performance enhancements to the accelerator and the CDF and D-Zero detectors. As discussed above, these efforts are proceeding in parallel with current Tevatron operations and research.

- OPERATION OF THE MINIBOONE AND MINOS FACILITIES AT FERMILAB AND THE SOUDAN MINE. The MiniBooNE experiment will be operating its beam line and detector to collect data. The MINOS far-detector at Soudan Mine will be in its final commissioning and pre-operations phase.

- FABRICATION AND SUPPORT FOR THE U.S. PORTION OF THE LHC PROJECT. The fabrication of the U.S. portion of the ATLAS and CMS detector components will continue along with the support for these detector activities. The production of the U.S. portion of the LHC accelerator components will also continue.

Subprogram Goals

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.

Performance Indicator

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

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Deliver data as planned (80 pb-1) to CDF and D-Zero detectors at the Tevatron. *[Met Goal]*	Deliver data as planned (225 pb-1) to CDF and D-Zero detectors at the Tevatron.	Deliver data as planned (400 pb-1) to CDF and D-Zero detectors at the Tevatron.
Collect data with the CDF and D-Zero detectors and begin analysis. *[Met Goal]*		Collect data using CDF and D-Zero detectors with high efficiency; record over 60% of available data and continue analysis.
		Using CDF and D-Zero data collected to this point, confirm or rule out some theoretical models of physics beyond the Standard Model (e.g., supersymmetry, large extra dimensions of space-time).

Develop high-intensity, accelerator-based neutrino beams, and specialized detectors, to perform decisive controlled measurements of fundamental neutrino properties, including neutrino oscillations, that will provide important clues and constraints to the theory of matter and energy beyond the Standard Model.

Performance Indicator

Validation of results by merit review with external peer evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Complete design of beamline components. Continue excavation of NuMI tunnels and halls. *[Met goal]*		Begin installation of beamline components. Complete installation of MINOS far detector.
Commission new MiniBooNE beamline and detector; begin data collection *[Met Goal]*.		Analyze MiniBooNE data to confirm or refute claims of neutrino oscillations observed in Los Alamos experiment.

Funding Schedule

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Proton Accelerator-Based Physics					
Research	71,948	74,369	72,765	-1,604	-2.1%
Facilities	316,169	313,517	326,729	+13,212	+4.2%
Total, Proton Accelerator-Based Physics	388,117	387,886	399,494	+11,608	+3.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Research	**71,948**	**74,369**	**72,765**
▪ **University Research**	**43,996**	**46,139**	**45,305**

The university program consists of groups at more than 60 universities doing experiments at proton accelerator facilities. These university groups plan, build, execute, analyze and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; and train graduate students and post-docs. University physicists typically constitute about 75% of the personnel needed to create, run, and analyze an experiment, and they usually work in collaboration with other university and laboratory groups. University-based research efforts will be selected based on peer review. Proton accelerator activities concentrate on experiments at the Tevatron complex at Fermilab; development of the physics program for the Large Hadron Collider, under construction at CERN; and the HERA accelerator complex at DESY in Germany.

In FY 2004, the university program is slightly decreased in order to provide support for high-priority Tevatron Operations, as part of the initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections, particularly searches for the Higgs boson and for supersymmetric particles. 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 and D-Zero, work to support the fabrication of the LHC detector components, and work on the preparation for U.S. participation in the LHC research program.

▪ **National Laboratory Research**	**27,131**	**26,843**	**26,073**

The national laboratory research program consists of groups at several laboratories participating in experiments at proton accelerator facilities. These groups participate in all phases of the experiments, with the focus of the physics program being similar to that of the university groups described above. Although they lack the specific educational mission of their colleagues at universities, they are imbedded in the laboratory structure, and therefore they provide invaluable

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

service to the research program in detector design, construction, and operations. The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers. Proton accelerator activities concentrate on experiments at the Tevatron complex at Fermilab; the Large Hadron Collider, under construction at CERN; and the HERA accelerator complex at DESY in Germany.

In FY 2004, the national laboratory research program is modestly decreased in order to provide support for high-priority Tevatron Operations, as part of the initiative to exploit the "window of opportunity" described above. Lower priority research efforts will be de-emphasized. The laboratory experimental physics research groups will be focused mainly on data-taking with the upgraded CDF and D-Zero collider detector facilities, and analysis of data taken in the FY 2003 collider run; preparation for operation of the MINOS detector; data taking with the MiniBOONE detector; support for the fabrication of the ATLAS and CMS detectors for the LHC; and for physicists working on preparation for U.S. participation in the LHC Research Program.

The Fermilab research program ($8,500,000) includes data taking and analysis of the CDF, D-Zero, and MiniBooNE experiments, CMS research and computing program, and commissioning of the MINOS detector. Being imbedded at the host laboratory, these activities provide the close linkages between the Research and the Facilities categories in the Proton Accelerator subprogram.

Research activities at LBNL ($5,300,000) will include data taking and analysis of the CDF and D-Zero experiments, and ATLAS research and computing program.

Activities by the BNL research group ($7,764,000) will cover data taking and analysis of the D-Zero experiment, ATLAS research and computing program, and a small effort on the MINOS experiment.

The research group at ANL ($4,509,000) will be working on data taking and analysis of the CDF experiment, ATLAS research and computing program, commissioning of the MINOS detector, and data taking and analysis of the ZEUS experiment at HERA.

▪ **University Service Accounts**...	**821**	**1,387**	**1,387**

University Service Accounts facilitate the support of university groups working at accelerator facilities, providing funding for these groups to purchase needed equipment and services from the laboratories with a minimum of time and cost overhead. Currently 45 university groups maintain service accounts at U.S. proton accelerator facilities.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Facilities	**316,169**	**313,517**	**326,729**

Facilities			
Tevatron Operations	191,958	181,638	190,955
Tevatron Improvements	49,677	51,589	57,240
Large Hadron Collider Project	49,000	60,000	48,800
Large Hadron Collider Support	5,775	6,730	15,400
AGS Operations/Support	6,012	0	0
Other Facilities	13,747	13,560	14,334
Total, Facilities	316,169	313,517	326,729

- **Tevatron Operations** **191,958** **181,638** **190,955**

Operations at Fermilab will include operation of the Tevatron accelerator complex in collider mode and operations of two collider detectors for about 36 weeks. This will be a major physics run with the higher intensity available from the Main Injector and with the upgraded D-Zero and CDF detectors to exploit the discovery "window of opportunity." This is to be one of the major data collection periods for the experiments searching for the Higgs and other physics topics from the energy frontier facility as described in more detail above. *The increased funding will provide support for the operations of the Tevatron and two detectors with an increased operations staffing to enhance the reliability and efficiency of the planned operations.*

The operation of the Tevatron collider complex has been disappointingly slow in achieving the desired beam intensities in the early phase (FY 2001-2002) of its major datataking run ("Run II"), perhaps diminishing some of the opportunities described above. Fermilab has assigned its highest priority to rectifying this situation. Internal resources have been redirected to solve the Tevatron performance issues, slowing progress on longer-term accelerator R&D projects that are not essential to the near-term goal of maximizing the Tevatron's ability to discover new physics. Due to this effort, the Tevatron is expected to meet its base luminosity goals in FY 2003-2004.

The extra resources needed to meet Tevatron Run II luminosity goals are mostly the efforts of accelerator and experimental research physicists at Fermilab, and are not incurring "extra" costs to the program. A few SLAC, LBNL and BNL accelerator physicists with specialized expertise relevant to Run II problems have been recruited to help as well.

Tevatron operations also include the running of the Tevatron complex in fixed target mode in parallel with Tevatron collider operation. This running mode will be primarily for the physics data taking of the MiniBooNE experiment (8 GeV proton extracted from Booster ring).

Tevatron Operations

	(in weeks)		
	FY 2002	FY 2003	FY 2004
Tevatron Operations	39	39	36

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▪ **Tevatron Improvements**	**49,677**	**51,589**	**57,240**

The funding will include the improvement of Tevatron operations as well as support for new and upgraded detectors associated with the Tevatron complex. The chance to discover the Higgs boson and other new physics before the LHC program is fully underway can be substantially increased with further improvements of the performance of the Tevatron and replacements of some of the components in the two collider detectors. Programs for improvement of the Tevatron performance are underway and the replacements of the detector components are being designed for installation in 2006. The funding will also provide the cost for the various utility improvement projects in order to operate Tevatron facilities with higher reliability and efficiency.

Plans for luminosity upgrades involve several steps toward increasing the number of antiprotons in the Tevatron, since that is the factor that limits the luminosity. Detector upgrades are needed to cope with the very high radiation load, or dose, on the inner tracking systems of the two collider detectors, that will result from the increased luminosity. The silicon tracker subsystem replacements will be necessary, since in the normal course of operation the silicon in the detectors will be damaged by radiation and will need 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 them to better withstand the higher intensities needed in the search for the Higgs. In addition, the large quantity of data from these experiments will require additional computing resources to carry out the data analysis. These enhancements will enable the Tevatron to run extensively with increased luminosity and therefore be able to provide enough data to find evidence of the Higgs if its mass is less than 165 GeV.

Funding in the amount of $33,300,000 is included for the program to increase the Tevatron luminosity, fabricate Run IIb 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 $5,600,000 over FY 2003. This includes capital equipment for continuation of the two projects including the replacement of the silicon tracker subsystems with new state-of-the-art radiation-hard silicon for both the CDF Detector ($8,396,000; TEC of $24,987,000) and D-Zero Detector ($8,588,000; TEC of $20,621,000). The TEC of the two Run IIb detector upgrade projects has increased since last year as conceptual designs have been developed and engineering estimates made. These TECs have now been finalized as an outcome of the baseline review in fall 2002.

The detector upgrades, general laboratory needs and AIP funding reflect the high priority given to highly effective operation of the Tevatron for the physics goals and are aimed at improving the luminosity and efficiency of the operation of the Tevatron.

MINOS is the detector part of the NuMI project that will provide a major new capability for neutrino research. *Capital equipment for the MINOS Detector is included at $2,000,000 (TEC $44,510,000). This is reduced from FY 2003 by $3,490,000 following the planned profile. Operating funding for the MINOS project is completed in FY 2003 leading to a decrease of $224,000 in FY 2004.*

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

Funding for Other Tevatron Improvement activities is increased (+$3,765,000) from FY 2003. Activities in this category includes support for ongoing Tevatron and detector operations, not related to identified upgrades, including: accelerator and detector maintenance activities, repair and replacement of failing or obsolescent components, and minor improvements and upgrades to existing systems. Also included is R&D for approved accelerator or detector upgrade projects. Activities included in this effort are design of an electron cooling system to improve the quality of an antiproton beam passed through the recycler ring. GPP funding is unchanged at $4,800,000 to assist with urgent ES&H and infrastructure needs.

	FY 2002	FY 2003	FY 2004
▪ **Large Hadron Collider Project**	**49,000**	**60,000**	**48,800**

The funding requested follows the currently approved profile, which is a revision from the original profile. Changes have been made to better match the funding profile to the funding needs of (1) the three U.S. LHC fabrication projects based on their current fabrication plans and schedules, and (2) the updated LHC construction schedule as determined by CERN. 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 in the CERN funded portion of the LHC project on the CERN site in Geneva, Switzerland have led to delays in the project. The problems are being overcome and the latest CERN schedule has first collisions in April 2007.

The detailed schedules of the three U.S. LHC projects have been reviewed in the context of this schedule revision by CERN. The U.S. LHC Accelerator Components Project will go forward without modification. The U.S. detector projects (ATLAS and CMS) will complete ~97% of their planned work by the previously scheduled end-date (4^{th} quarter FY 2005), but for each a small amount of work is intimately tied to the late stages of the CERN schedule. This is primarily work directly related to the final assembly, testing, and installation of the full detectors, as well as purchase of computing hardware for data acquisition. Under the current schedule, this work will occur in 2006 and 2007, changing the final project completion date. The increased costs arising from the delay are modest and will be contained within the projects contingency allowances. **The final cost of each detector is unchanged.**

The result of these changes is a stretch out of the planned U.S. contributions to the LHC by two years. *The FY 2004 funding for the detectors is reduced and the funds rescheduled in FY 2006 and FY 2007.*

CERN initiated the 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 opening up substantial new frontiers for scientific discovery.

Participation by the U.S. in the LHC program is extremely important to U.S. High Energy Physics program goals. The LHC will become the foremost high energy physics research facility in the world when it begins commissioning in 2007. 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 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. LHC has strong potential for answering the question of the origin of mass. The LHC energies are sufficient to test theoretical arguments for a totally new type of matter. In addition, history shows that major increases in the particle energy nearly always yield unexpected discoveries.

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

Participation in the LHC project (accelerator and detectors) at CERN 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 (with an additional $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% 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

(dollars in thousands)

FY 2002	FY 2003	FY 2004

research program at the LHC. This physicist involvement has already begun. Over 600 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] (Detector)
	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	19,470	48,800	0
2005	20,657	11,053	31,710	0
2006[c]	0	7,440	7,440	0
2007	0	3,180	3,180	0
Total	200,000[d]	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] At the end of FY 2005 approximately 97% of the U.S. CMS and U.S. ATLAS projects will be completed on schedule. The remaining 3% of the project scope is integrally connected to the CERN portion of the project. As such, the recent slip in the CERN project schedule will significantly impact our ability to complete the remaining 3% of this project on the present schedule. The 97% portion of this project that will be complete at the end of FY 2005 will be closed out at that time. The remaining 3% of the project will continue, consistent with all DOE project management policies and practices. Based on CERN's current schedule, it is anticipated that the remaining work will be completed by the end of FY 2008, with no change in the total estimated cost of the project.

[d] 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 2002	FY 2003	FY 2004
LHC			
Accelerator Systems			
Operating Expenses	1,900	1,850	1,830
Capital Equipment	8,196	6,850	4,300
Total, Accelerator Systems	10,096	8,700	6,130
Procurement from Industry	11,207	13,400	23,200
ATLAS Detector			
Operating Expenses	2,865	7,282	4,280
Capital Equipment	7,642	10,134	4,710
Total, ATLAS Detector	10,507	17,416	8,990
CMS Detector			
Operating Expenses	11,190	11,000	6,550
Capital Equipment	6,000	9,484	3,930
Total, CMS Detector	17,190	20,484	10,480
Total, LHC	49,000	60,000	48,800

Changes have been made by each of the three U.S. projects, and approved by DOE project management, based on actual expenditures and progress during FY 2002, and updated planning based on the FY 2002 experience.

In FY 2004, funding will be used for the fabrication of accelerator magnets and equipment and the 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.

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		
► **Accelerator Systems**	**10,096**	**8,700**	**6,130**

In FY 2004, funding will support continued production of quadrupole magnets, cryogenic/ electrical power feedboxes, and beam absorbers for the LHC beam interaction regions. Shipments to CERN 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. *Funding is reduced by $2,570,000 as production activities continue to ramp down.*

► **Procurement from Industry**	**11,207**	**13,400**	**23,200**

In FY 2004, 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 $9,800,000 to support the current estimate of actual CERN payments to U.S. industrial suppliers which are expected to peak in 2004.*

► **ATLAS Detector**	**10,507**	**17,416**	**8,990**

In FY 2004, 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 barrel, the silicon inner tracker and the muon drift test chambers will be completed. The delivery to CERN of various detector components will continue. Fabrication of the detector trigger and data acquisition system will begin. *Funding is decreased by $8,426,000 to follow the ramp-down on production of detector components.*

► **CMS Detector**	**17,190**	**20,484**	**10,480**

In FY 2004, 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 and production assembly of the silicon detector layers will continue in the U.S. *Funding is decreased by $10,004,000 to follow the ramp-down on production of detector components.*

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		
▪ **Large Hadron Collider Support**	**5,775**	**6,730**	**15,400**

In FY 2004, LHC Support work will concentrate on the preparation for U.S. participation in the LHC research program. The main use of the resources will be for LHC software and computing, and pre-operations for the U.S.-built systems that are part of the LHC detectors. The U.S. LHC effort is one of the high priority components of the HEP program and has been repeatedly endorsed by HEPAP. *Significant increases in this area are planned for FY 2004 to meet the urgent and growing need for LHC support activities in advance of LHC turn-on in 2007.*

The LHC software and computing effort will enable U.S. physicists to analyze the vast quantity of LHC data in a transparent manner, and empower them to take a leading role in exploiting the physics opportunities presented by the LHC. In FY 2004 the U.S. software efforts will be focused on "data challenges" where a significant fraction (~10%) of the hardware needed for full LHC data analysis will be tested with professional-quality software on simulated data. These systems need to grow rapidly from prototypes, capable of handling a few percent of the eventual data in 2002, to fully-functional 10%-scale systems in 2004 (comparable to the full data analysis systems for the CDF or D-Zero experiments at Fermilab).

Funding for pre-operations and operations of the LHC detector subsystems built by U.S. physicists will also start to ramp-up significantly in FY 2004 as LHC turn-on approaches. U.S. CMS collaborators will be performing vertical integration tests of the major detector subsystems that they built, using functional prototypes of the final data acquisition system, in advance of their final installation in the underground cavern. U.S. ATLAS collaborators will be performing testing and commissioning of most detector subsystems. A small effort focused on R&D for specific possible LHC accelerator and detector upgrades will continue.

▪ **AGS Operations/Support**	**6,012**	**0**	**0**

Operations at BNL for HEP experiments using the AGS facility were terminated at the end of FY 2002.

▪ **Other Facilities**	**13,747**	**13,560**	**14,334**

Includes funding for private institutions and other government laboratories and institutions that participate in high energy physics research.

Includes $1,624,000 for General Purpose Equipment and $3,500,000 for General Plant Projects at LBNL for landlord related activities.

This category also includes funding to respond to new opportunities and unexpected changes in facilities operations and support.

Total, Proton Accelerator-Based Physics	**388,117**	**387,886**	**399,494**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Research	
▪ In University Research, a decrease of $834,000 is taken in order to provide support for maintaining high priority Tevatron improvements and operations	-834
▪ In National Laboratory Research, a decrease of $770,000 is taken in order to provide support for maintaining high priority Tevatron improvements and operations.	-770
Total, Research	-1,604
Facilities	
▪ In Tevatron Operations, an additional $9,317,000 is provided for increased support for operations of the Tevatron Complex. This includes significant additional personnel to handle the demands of high-luminosity Tevatron running, as well as preparation for the NuMI/MINOS program using the Main Injector in fixed-target mode beginning in 2005	+9,317
▪ In Tevatron Improvements, $5,600,000 is provided for increased support for the high priority upgrades of the Tevatron complex. This is offset by decreases of $3,490,000 in capital equipment and $224,000 in operating funding for the MINOS project as reflected in the approved profile, increases in support activities of $3,990,000, and a decrease of $225,000 in motor vehicle purchases.	+5,651
▪ In the Large Hadron Collider project, a decrease of $11,200,000 follows the new funding profile that reflects the changes to the CERN LHC completion date and its impact on the U.S. portions of the LHC detector sub-projects. These funds are restored in FY 2006 and FY 2007 so that the total project cost is unchanged. The accelerator funding ramps down as it nears completion	-11,200
▪ In Large Hadron Collider Support, an increase of $8,670,000 is provided in part for significantly increased effort in providing the computing systems and networks needed to effectively handle and process the large volume of LHC data. The support for the detector pre-operations is also significantly increased, as detector testing and commissioning activities are ramping up in 2004. A small accelerator R&D effort focused on LHC machine improvements also increases	+8,670
▪ In Other Facilities, an increase of $1,100,000 in funds is held pending completion of peer review and/or programmatic review, offset by a reduction of $326,000 in GPE at LBNL related to motor vehicle purchases.	+774
Total, Facilities	+13,212
Total Funding Change, Proton Accelerator-Based Physics	**+11,608**

Electron Accelerator-Based Physics

Mission Supporting Goals and Measures

The Electron Accelerator-Based Physics subprogram utilizes the high data rates achievable at the SLAC B-factory and other electron-positron colliding beam facilities to perform an experimental program to understand Charge-Parity (CP) violation in electroweak interactions, and therefore the excess of matter over antimatter in the universe.

Introduction

While electron accelerators can be used to study a wide variety of physics topics, and historically have been so used, the current electron accelerator subprogram is focused on the study of charm and bottom quarks and the tau lepton. These particles are all heavier than the particles of everyday matter and well suited for studying rare processes. The most interesting of these processes is CP violation, which is needed to explain the fact that our universe is mostly made of matter and not antimatter.

CP violation has been observed in the decays of particles containing strange quarks (*K* mesons) and most recently in particles containing bottom quarks (B mesons). This most recent observation has been made at the SLAC B-factory and the KEK-B accelerator in Japan. Now that the first observations of CP violation in B mesons have been made, it is possible to do a systematic study of the process and test whether our current theoretical explanation of CP violation, the Standard Model, is correct. This systematic study will require both new measurements of CP violation in other B meson decays, and measurements of other properties of particles containing bottom or charm quarks. The measurements of these other properties are used as inputs to the theoretical calculations of CP violation, and our limited current knowledge of those properties also limits our understanding of CP violation.

The BaBar experiment at the SLAC B-factory will pursue a broad program of physics studies on particles containing bottom or charm quarks with CP violation measurements being its highest priority, but other measurements that support or complement the CP violation program will also be pursued. The Belle experiment at the KEK-B accelerator in Japan has a very similar program planned. A small number of U.S. university researchers participate in the Belle experiment. There is regular cooperation as well as competition between the BaBar and Belle experiments, which has led to a better understanding of how to run the accelerators and detectors and do the data analysis leading to results that are more precise. The CLEO-C experiment at the Cornell Electron Storage ring is concentrating on certain precision measurements of particles containing charmed quarks, which are difficult to do at the B-factory. These are used both for testing the theories used to interpret the CP violation measurements as input to the physics analyses done at the B-factory.

Research and Facilities

The Research category in the Electron Accelerator subprogram supports the university and laboratory based scientists performing experimental research at electron accelerator facilities in the U.S. and abroad. Experimental research activities are collaborative efforts by research groups from LBNL, LLNL, SLAC, and about 40 colleges and universities and include: planning, design, fabrication and installation of experiments and associated computing infrastructure; preparation for experimental operations and conduct of experiments; analysis and interpretation of data; and publication of results. These research programs are carried out at various facilities where the accelerators and detectors are located. The university program also includes a small amount of funds at national laboratories (so-called "university service accounts") to allow university groups to perform specific tasks connected with the experimental research program, such as purchasing needed equipment from laboratory stores.

The Facilities category in the Electron Accelerator subprogram supports the maintenance and operations of, and technical improvements to, electron accelerator facilities in the U.S. Facilities activities include: installation, commissioning, maintenance and operations of accelerators and experiments; providing computing hardware and software infrastructure to support the experiments and the accelerators, and provide platforms for data analysis; and directed R&D for accelerator and detector enhancements and performance improvements. Since physicists are often involved in these activities as well as research activities, some are partially supported by both categories of funding where appropriate

The electron accelerator facilities support personnel are based primarily at LBNL, LLNL, and SLAC, working together with the experimental groups from various universities and foreign institutions.

Highlights

Recent accomplishments include:

- In 2002, physicists using the BaBar detector at the SLAC B-factory announced new, improved measurements 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 their earlier results announced in 2001. The BELLE experiment also reported a new observation of CP violation in the B-meson system (via a different B-decay channel), but BaBar has not confirmed this result. All data collected to date are consistent with the current Standard Model description of CP violation. Data collection continues at a high rate to improve the precision of the results, look for evidence in new modes, and resolve any discrepancies.

The major planned research efforts in FY 2004 are:

- THE RESEARCH PROGRAM AT THE B-FACTORY/BABAR FACILITY AT SLAC. This research program is being carried out by a collaboration of approximately 550 physicists including scientists from LBNL, LLNL, ORNL, SLAC, 35 U.S. universities, and institutions from 7 foreign countries.
- THE RESEARCH PROGRAM AT OTHER ELECTRON ACCELERATOR FACILITIES. This program complements the B-factory/BaBar efforts and consists of a group of experimental research activities using the Cornell Electron Storage Ring (CESR) and the KEK-B electron accelerator facilities. A total of 4 U.S. university groups work at KEK-B, and 19 U.S. university groups work at CESR.

The major planned facilities efforts in FY 2004 are:

- OPERATIONS OF THE B-FACTORY AT SLAC. SLAC plans 39 weeks of running to achieve a performance goal of 50 fb^{-1} of data delivered to the BaBar experiment. Approximately 450 people are involved in day-to-day B-factory operations.

- PLANNING AND PREPARATION FOR B-FACTORY/BABAR PERFORMANCE ENHANCEMENTS. Fully achieving the physics goals of the B-factory program over the next five years requires a series of performance enhancements to the accelerator and the BaBar detectors. These efforts are proceeding in parallel with current B-factory operations and research.

Subprogram Goal

Explain the observed absence of antimatter in the universe through understanding of the phenomenon of Charge-Parity (CP) Violation.

Performance Indicator

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

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Increase the total data delivered to BABAR at the SLAC B-factory by delivering 35 fb-1 of total luminosity. *[Met Goal]*	Increase the total data delivered to BABAR at the SLAC B-factory by delivering 45 fb-1 of total luminosity.	Increase the total data delivered to BABAR at the SLAC B-factory by delivering 50 fb-1 of total luminosity.
	Add one new RF station to allow for increased beam intensity	Add one new RF station to allow for increased beam intensity.
Collect data using the BaBar detector with high efficiency; record over 90% of delivered data and continue analysis. *[Met Goal]*		Collect data using the BaBar detector with high efficiency; record over 90% of delivered data and continue analysis.
Using the BaBar dataset, measure CP violation in a single class of decay process ("golden modes") of B mesons with an uncertainty of +/- 0.12. *[Met Goal]*	Using the BaBar dataset, measure CP violation in a single class of decay process ("golden modes") of B mesons with an uncertainty of +/- 0.06.	Using the BaBar dataset, begin measuring CP violation (CPV) in new classes of rare decay modes with an uncertainty of +/- 0.4. Compare with existing measurements in other areas (e.g., B meson "golden modes," CPV in K mesons) to search for non-Standard Model CPV in the B meson system.

Funding Schedule

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Electron Accelerator-Based Physics					
Research	30,303	33,063	33,643	+580	+1.7%
Facilities	117,929	117,085	125,843	+8,758	+7.5%
Total, Electron Accelerator-Based Physics	148,232	150,148	159,486	+9,338	+6.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Research	**30,303**	**33,063**	**33,643**
▪ **University Research**	**20,160**	**22,777**	**23,007**

The university program consists of groups at about 40 universities doing experiments at electron accelerator facilities. These university groups plan, build, execute, analyze and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; and train graduate students and post-docs. The current electron accelerator subprogram is focused on the study of charm and bottom quarks and the tau lepton which are all heavier than the particles of everyday matter and well suited for studying rare processes. The most interesting of these processes is CP violation, which is needed to explain the fact that our universe is mostly made of matter and not antimatter. The BaBar experiment at the SLAC B-factory will pursue a broad program of physics studies on particles containing bottom or charm quarks with CP violation measurements being its highest priority, but other measurements that support or complement the CP violation program will also be pursued.

U.S. university physicists constitute about 50% of the personnel needed to create, run, and analyze the BaBar experiment at the B-factory, and they work in collaboration with groups from national laboratories and foreign institutions.

The university program also supports nine groups that work at the Cornell Electron Storage Ring at Cornell University; and four groups that work at the KEK-B accelerator complex at KEK in Japan. The CLEO-C experiment at the Cornell Electron Storage ring is concentrating on certain precision measurements of particles containing charmed quarks, which are difficult to do at the B-factory. There is regular cooperation as well as competition between the SLAC and KEK experiments, which has led to a better understanding of how to run the accelerators and detectors and do the data analysis leading to physics results that are more precise than they would be otherwise. University-based research efforts will be selected based on peer review.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

In FY 2004, the university program is increased slightly 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, particularly to support analysis of the unprecedented amount of physics data generated by the B-factory and other electron accelerators. 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 BaBar.

▪ **National Laboratory Research**	**9,992**	**9,981**	**10,331**

The national laboratory research program consists of groups at several laboratories participating in experiments at electron accelerator facilities with a physics program similar to the university program described above. In FY 2004, the laboratory experimental physics research groups will be focused mainly on data-taking with the BaBar detector, analysis of data taken in earlier runs, and planning for detector enhancements needed for future runs. The laboratory research program is increased slightly to provide support for those groups involved in the initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections, particularly to support analysis of the unprecedented amount of physics data generated by the B-factory and other electron accelerators.

The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers.

The experimental research group from SLAC ($7,058,000) participates in all phases of the experiments. Because they are imbedded in the laboratory structure, they provide invaluable service in the design, construction, and calibration, and operations of the detector, as well as the reconstruction and analysis of the data.

The experimental research group at LBNL ($2,975,000) has broad responsibilities on the BaBar experiment. The group is second in size with only the SLAC group being larger. They were responsible for constructing and commissioning significant portions of the charged particle tracking detectors and their electronics. Now they contribute to operating, maintaining and calibrating the detector. They also make significant contributions to the computing system used to control the detector and acquire the data, and the computing system used to reconstruct the data into physics quantities used for analysis.

The efforts from LLNL ($298,000) are much smaller, limited to only a handful of scientists working on the BaBar experiment.

▪ **University Service Accounts**	**151**	**305**	**305**

University Service Accounts facilitate the support of university groups working at accelerator facilities, providing funding for these groups to purchase needed equipment and services from the laboratories with a minimum of time and cost overhead. Currently 16 university groups maintain service accounts at U.S. electron accelerator facilities.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Facilities	**117,929**	**117,085**	**125,843**
▪ **B-factory Operations**	**97,334**	**97,275**	**104,225**

Funding for operations supports running the accelerator for 39 weeks, the operation of the BaBar detector for data collection, and computing support to analyze the collected data. This will be the priority research program at SLAC in FY 2004. It is anticipated that the collected data will significantly exceed the total collected in FY 2003. *Funding increases due to the higher luminosity running.* More electric power is required to run the accelerator at higher luminosity, so power costs are up.

The fixed target research program in End Station A is not planned to run in FY 2004, due to overall budget constraints and the high priority assigned to B-factory operations.

SLAC Operation

	(in weeks)		
	FY 2002	FY 2003	FY 2004
Fixed Target[a]	8	8	0
B-factory Operation	35	39	39
Total, SLAC Operation	35	39	39

▪ **B-factory Improvements**	**20,595**	**19,810**	**21,618**

An important component of the FY 2004 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 $3 \times 10^{34} cm^{-2} s^{-1}$, 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.

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 $12,200,000. *This is an increase of $4,500,000 over FY 2003.* The projects include upgrades to B-factory vacuum and acceleration systems, and continuous enhancement of computing capabilities to keep pace with the flood of data the B-factory provides.

Funding for Other B-factory Improvement activities is decreased (-$2,692,000) from FY 2003. Activities in this category include support for ongoing B-factory and detector operations, not related to identified upgrades, including: accelerator and detector maintenance activities, repair and replacement of failing or obsolescent components, and minor improvements and upgrades to existing

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

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

systems. Also included is R&D for approved accelerator or detector upgrade projects. This effort includes design of a new interaction region for the B-factory that would allow the electron and positron beams to cross at an angle instead of head-on, which has the potential to significantly increase machine luminosity. GPP funding is unchanged at $4,200,000 to assist with urgent ES&H and infrastructure needs.

In FY 2004, the emphasis will be on work to support and improve performance of the BaBar detector and upgrade the associated computing systems to handle the unprecedented data volumes being generated by the excellent performance of the B-factory.

Total, Electron Accelerator-Based Physics	**148,232**	**150,148**	**159,486**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Research	
▪ In University Research, an additional $230,000 is provided for maintaining effort on the BaBar research program.	+230
▪ In National Laboratory Research, an additional $350,000 is provided for maintaining effort on the BaBar research program.	+350
Total, Research	+580
Facilities	
▪ In B-factory Operations, an additional $6,950,000 is provided for operation of the B-factory complex to help address projected increased in power costs and meet performance targets.	+6,950
▪ In B-factory Improvements, $4,500,000 is provided for increased support for the upgrades of the B-factory complex. This is partially offset by a reduction of $2,540,000 for other B-factory support activities including maintenance and repair, reflecting the high priority of B-factory upgrades, and a decrease of $152,000 for motor vehicle purchases.	+1,808
Total, Facilities	+8,758
Total Funding Change, Electron Accelerator-Based Physics	**+9,338**

Non-Accelerator Physics

Mission Supporting Goals and Measures

The Non-Accelerator Physics subprogram provides U.S. leadership in the study of those aspects of elementary particles and their interactions that cannot be determined solely through the use of accelerators. These activities have the capability of probing beyond the Standard Model of particle physics in many areas, enriching the accelerator-based subprograms with complementary experimental data, new ideas and techniques.

Introduction

Non-Accelerator Physics is playing an increasingly important role in High Energy Physics, using ever more sophisticated techniques to probe fundamental physics questions using naturally occurring particles. University and laboratory scientists in this subprogram pursue searches for rare and exotic particles or processes, such as dark matter, dark energy, Majorana neutrinos, proton decay, the highest energy cosmic rays, or primordial antimatter. They also study the properties of neutrinos from the sun, galactic supernovae, and cosmic rays in the earth's atmosphere. In addition, high energy gamma ray observations probe the highest energy phenomena observed in nature and yield information about possible black holes or active nuclei at the centers of galaxies. These areas of research probe well beyond the Standard Model of particle physics and offer possibilities for discovery of significant new physics. Using particle physics techniques and in some cases the infrastructure of our national laboratories, most of the experiments are located at remote sites, such as in deep underground laboratories, on mountain tops, spread over expansive deserts, or in space, either as dedicated satellites or as instruments attached to the International Space Station.

Research and Facilities

The Non-Accelerator Physics subprogram supports the university and laboratory scientists performing experimental particle physics and astrophysics research in the U.S. and abroad that does not directly involve the use of high energy accelerator particle beams. The research groups are based at about 35 colleges and universities. This program is carried out in collaboration with physicists from five DOE national laboratories (Fermilab, SLAC, LBNL, ANL, and LANL) and other government agencies including NASA, NSF, NRL, and the Smithsonian Astrophysical Observatory. Strong interagency coordination and collaboration is one of the hallmarks of the projects in this subprogram. As with the rest of the HEP portfolio, most projects involve international collaboration in all phases of the experiment.

The Non-Accelerator Physics subprogram includes support for special facilities and research groups to perform these experimental measurements. While research groups are covered under the Research categories, the Projects category in the Non-Accelerator Physics subprogram supports the technical R&D, engineering and design, detector apparatus, and remote site operations of Non-Accelerator Physics projects. Remote sites include the Soudan Mine in Minnesota, the Kamiokande Mine in Japan, the Whipple Observatory in Arizona, the Pierre Auger Laboratory in Argentina, the Stanford Underground Facility at Stanford University, and the Gran Sasso Laboratory in Italy. Other operations include the ground-based laboratories for Gamma-ray Large Area Space Telescope (GLAST) Large Area Telescope (LAT) at SLAC and for AMS at Massachusetts Institute of Technology (MIT).

Highlights

Recent accomplishments include:

- The Pierre Auger Project in Argentina to observe ultra-high energy cosmic rays completed an engineering array in FY 2002 consisting of 40 air-shower detectors and 2 resonance fluorescence detectors. The full array of 1600 air-shower detectors and 4 fluorescence detectors will be completed in 2005 by an international collaboration, but physics measurements will commence in 2002.
- In December 2002, after six months of running, KamLAND's first results were announced, showing a deficit in the flux of neutrinos. KamLAND is an underground neutrino experiment in Japan which detects neutrinos generated by several Japanese nuclear reactors. This result indicates that neutrinos have mass and are not stable in time, oscillating into other types of neutrinos. The KamLAND results make the case for oscillations and neutrino mass seemingly inescapable, since neutrinos were directly measured "disappearing" after leaving the nuclear reactors on their flight to the detector.

The major planned efforts in FY 2004 are:

- FABRICATION OF THE GLAST/LAT TELESCOPE. DOE and NASA are partners on the LAT, the primary instrument to be flown on the space-based NASA-GLAST Mission, scheduled for launch in 2006. Its goals are to observe and understand the highest energy gamma rays observed in nature and yield information about extreme particle accelerators in space, including possible black holes or active nuclei at the centers of galaxies, using particle physics detection techniques. This research program is being carried out by a collaboration, which includes scientists from SLAC, NASA, NRL, U.S. universities, and institutions from Italy, France, Japan, and Sweden. The LAT's high energy gamma ray observations will probe the highest energy phenomena in nature and yield information about a variety of scientific topics of interest to astrophysicists, cosmologists and particle physicists, including high-energy, extragalactic light sources and dark matter.
- FABRICATION OF THE VERITAS TELESCOPE ARRAY. VERITAS is a new multi-telescope array that will study astronomical sources of high energy gamma rays, from about 100 GeV to about 10 TeV. This facility will complement the GLAST/LAT telescope which does the same physics up to about 100 GeV. There is particular interest in gamma rays from poorly-understood astronomical sources such as Active Galactic Nuclei and Gamma Ray Bursters, and searches for signatures of supersymmetric dark matter. The experimental technique was developed by the DOE-supported researchers at the Harvard-Smithsonian Whipple Observatory on Mt. Hopkins in Arizona, and the project is supported by a partnership between DOE, NSF and the Smithsonian Institution. Fabrication will begin in FY 2004 and be completed in three years.
- COMPLETE FABRICATION AND BEGIN OPERATION OF THE PIERRE AUGER OBSERVATORY. The Southern Auger Observatory is a very large area cosmic ray detector, covering about 3,000 square kilometers, whose goal is to observe, understand and characterize the very highest energy cosmic rays. The southern array is under construction on the pampas of Mendosa, Argentina. This research program is being carried out by an international collaboration including scientists from U.S. universities, Fermilab, and institutions from 19 foreign countries. The

U.S. part of the project is funded jointly with NSF and a significant contribution from the University of Chicago. Fermilab provides the project management team.

- COMPLETE FABRICATION AND BEGIN OPERATION OF THE CRYOGENIC DARK MATTER SEARCH (CDMS). CDMS-II is the most sensitive direct search for super-symmetric dark matter undertaken to date. It consists of specially developed cryogenic silicon and germanium detectors with dual ionization and phonon signal capabilities. These detectors must operate at very low temperature (25 milliKelvin) in a cryostat located deep underground at the Soudan Mine Laboratory in Northern Minnesota. This research program is being carried out by a collaboration including scientists from U.S. universities, Fermilab, and LBNL. The project is funded jointly with NSF and Fermilab provides the project management team.
- RESEARCH, DEVELOPMENT, AND CONCEPTUAL DESIGN FOR THE PROPOSED SUPERNOVA ACCELERATION PROBE (SNAP) EXPERIMENT. LBNL is leading an effort to develop a dedicated satellite experiment to discover and precisely measure thousands of type Ia supernovae, which will be studied to determine the equation of state of the universe and the mechanism responsible for the accelerating expansion of the universe. The goal of this experiment is to understand the phenomena of "dark energy." The research is carried out by a collaboration including scientists from U.S. universities and LBNL.

Subprogram Goal

Develop a world-class, peer-reviewed research program of non-accelerator-based research in particle astrophysics and cosmology that builds on unique capabilities developed for HEP.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Approve preliminary project baseline range (CD-1) for the Large Area Telescope (LAT) to be flown on the NASA GLAST mission The mission goals are to observe and understand high-energy gamma ray emissions using technology developed for HEP research. Launch is scheduled for FY 2006. *[Met goal]*		Complete mechanical support structure ("flight grid") for LAT instrument.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Continue R&D in pre-conceptual planning phase for SuperNova Acceleration Probe (SNAP). Determine project plan for R&D phase. The goal of this experiment is to understand the phenomena of "dark energy" that is causing the accelerating expansion of the universe. *[Met Goal]*		R&D work in Preliminary Design Phase towards Conceptual Design Report for SNAP experiment.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Non-Accelerator Physics					
University Research	9,741	10,935	11,539	+604	+5.5%
National Laboratory Research	14,136	12,900	11,800	-1,100	-8.5%
Projects	14,378	13,230	19,306	+6,076	+45.9%
Other	860	355	355	0	0.0%
Total, Non-Accelerator Physics	39,115	37,420	43,000	+5,580	+14.9%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
University Research	**9,741**	**10,935**	**11,539**

The university program consists of groups at more than 35 universities doing experiments at Non-Accelerator Physics facilities, using ever more sophisticated techniques to probe fundamental physics questions using naturally occurring particles. Scientists in this subprogram pursue searches for rare and exotic particles or processes, such as dark matter, dark energy, Majorana neutrinos, proton decay, the highest energy cosmic rays, or primordial antimatter. They also study the properties of neutrinos from the sun, galactic supernovae, and cosmic rays in the earth's atmosphere. In addition, high energy gamma ray observations probe the highest energy phenomena observed in nature and yield information about possible black holes or active nuclei at the centers of galaxies. These areas of research probe well beyond the Standard Model of particle physics and offer possibilities for discovery of significant new physics.

These university groups plan, build, execute, analyze and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; develop new theoretical models and provide interpretations of existing experimental data; and train graduate students and post-docs. University physicists in this research area often work in collaboration with other university and laboratory groups. University-based research efforts will be selected based on peer review.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

In FY 2004, the university program in non-accelerator physics will provide increased support for those universities involved in projects that may yield exciting new physics. To the extent possible, the detailed funding allocations will take into account the discovery potential of the proposed research. One notable example is the AMS experiment, whose goal is to detect sources of extra-galactic antimatter, using an instrument attached to the International Space Station. In FY 2004, the AMS collaboration will continue preparation for the planned 2006 launch. This project is led by scientists at MIT and consists of a collaboration of NASA, multiple U.S. universities, and numerous international institutions.

Other research efforts that will be continuing in this subprogram include: KamLAND, an underground neutrino oscillation detector which detects reactor-produced neutrinos in Japan; Super-Kamiokande, a proton decay, solar and atmospheric neutrino detector located in the Kamioka Underground Laboratory in Japan; and Zeplin-II, a Xenon dark matter detector located in an underground laboratory in Boulby, United Kingdom.

National Laboratory Research	**14,136**	**12,900**	**11,800**

The national laboratory research program consists of groups at several laboratories participating in Non-Accelerator Physics experiments similar to the university physics program described above. With strong laboratory technical resources, they provide invaluable service to the research program in detector design, construction, and operations. The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers.

In FY 2004, the laboratory experimental physics research groups (including groups at LBNL, Fermilab and SLAC) will be focused mainly on supporting the fabrication of the GLAST/LAT telescope and analysis of previous experimental data (SLAC); analysis of initial data from the prototype Auger array and the CDMS-II detector and continuing data analysis from the Sloan Digital Sky Survey (Fermilab); and research and development for the SNAP experiment proposal and continued analysis of data from KamLAND (LBNL).

Projects	**14,378**	**13,230**	**19,306**

In FY 2004, this effort will be focused mainly on fabrication of the GLAST/LAT telescope, deployment of the prototype Auger array, installation of the Phase-I CDMS detector, R&D for the proposed SNAP experiment, and initial fabrication of VERITAS, a ground-based telescope to study high energy astrophysical gamma ray emissions, complementary to GLAST/LAT.

The FY 2004 GLAST/LAT program ($7,900,000; TEC of $37,000,000) will focus on the fabrication of the LAT instrument, and integration of components in preparation for launch on the GLAST mission in 2006, and development of the data analysis capability at SLAC. Project baseline cost range was finalized in FY 2002.

The FY 2004 CDMS program ($550,000; TEC of $4,918,000) will focus on completion of the cryogenic detector towers, taking data with already completed towers, and on the development of the data analysis and publication of preliminary results.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

The FY 2004 program for VERITAS ($1,600,000; TEC of $4,799,000) will concentrate on completion and final certification of the telescope prototype built in FY 2003, and beginning the fabrication phase for the full telescope array.

In FY 2004, the U.S. effort on the Pierre Auger project may take an additional scope to assist in completion of the full detector array. Funding for this effort ($1,000,000; TEC of $3,250,000) is planned pending completion of peer review and programmatic decisions.

The FY 2004 SNAP program ($8,256,000) will focus on developing a conceptual design, the beginning of engineering design, and fabrication and testing of prototypes for the principal SNAP instrument. *The goal of this R&D effort is to produce a complete Conceptual Design Report by 2006, and funding is increased by $6,876,000 to provide the significant resources needed to successfully begin the detailed design and prototyping phase. This increase is consistent with the 2002 HEPAP Subpanel recommendation that the physics of SNAP (the "dark energy" phenomenon) is exciting and relevant to HEP, and that the R&D effort should be supported; and the recent National Research Council report ("Quarks to the Cosmos") which identified this interdisciplinary research area as a high priority for an interagency initiative.* DOE is actively engaged with NASA to develop a successful research effort in this new and exciting field.

Other	**860**	**355**	**355**

Includes funding for private institutions and other government laboratories and institutions that participate in non-accelerator based physics research. This category also includes funding for conferences, studies, and workshops, funding for research activities that have not yet completed peer review, and to respond to new and unexpected physics opportunities.

Total, Non-Accelerator Physics	**39,115**	**37,420**	**43,000**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
University Research	
▪ An increase of $604,000 for university groups to increase effort on Non-Accelerator projects.	+604
National Laboratory Research	
▪ A decrease of $1,100,000 at Fermilab reflecting a reduced involvement in Non-Accelerator projects.	-1,100

	FY 2004 vs. FY 2003 ($000)
Projects	
▪ An increase of $6,876,000 is provided for the SNAP R&D program to begin conceptual design and fabrication and testing of detector prototypes, and an increase of $1,600,000 is provided to initiate VERITAS. This is offset by a $750,000 decrease reflecting the completion of funding for the AMS project; decreases in GLAST/LAT ($-1,010,000) and CDMS ($-250,000) are consistent with the planned profiles. The decrease of $1,250,000 due to completion of Phase I of the Auger project is partly offset by the set aside of $1,000,000 pending clarification and review of the proposed increase in the U.S. responsibilities in the Auger project. There is also a decrease of $140,000 in funds held for programmatic consideration, for a net increase of $6,076,000 in Projects	+6,076
Total Funding Change, Non-Accelerator Physics	**+5,580**

Theoretical Physics

Mission Supporting Goals and Measures

The Theoretical Physics subprogram provides the framework for interpreting and understanding the results of high energy physics measurements. It includes activities ranging from detailed calculations of the predictions of the Standard Model of elementary particles to the investigation of informed speculations about what new phenomena may await discovery and how to search for them most efficaciously. The Theoretical Physics subprogram also includes strong components engaged in trying to extend the understanding achieved into the realm of cosmology in order to illuminate the history and early evolution of the universe.

Introduction

Though they are typically not directly involved in the planning, design, fabrication or operations of experiments, theoretical physicists play key roles in determining *what kinds* of experiments would likely be the most interesting to perform, and in *explaining* experimental results in terms of a fundamental underlying theory that describes all of the components and interactions of matter, energy, space and time. The research activities supported by the Theoretical Physics subprogram include calculations in the quantum field theories of the elementary particles that constitute the Standard Model and developing other models for elementary particle processes; interpreting results of measurements in the context of these models; identifying where new physical principles are needed and what their other consequences may be; developing and exploiting new mathematical and computational methods for analyzing theoretical models; and constructing and exploiting powerful computational facilities for theoretical calculations of especial importance for the experimental program. Major themes are symmetry and unification in the description of diverse phenomena.

Research at Universities and National Laboratories

The University and National Laboratory categories of the Theoretical Physics subprogram support scientists performing research in theoretical high energy physics and related areas of theoretical physics. The research groups are based at approximately 75 colleges and universities and at 6 DOE High Energy Physics and multiprogram laboratories (Fermilab, SLAC, BNL, ANL, LBNL, LANL).

The Theoretical Physics subprogram involves collaborations between scientists based at different universities and laboratories, and also collaborations between scientists supported by this program and others whose research is supported by other Offices of the DOE and by other federal agencies, including NASA and NSF. There are also many international collaborations in theoretical physics research. These collaborations are typically smaller and more informal than the efforts required to mount large experiments.

The Theoretical Physics subprogram also includes support for special facilities for numerical and algebraic computation of developed theories, and for research groups to carry out these activities.

SciDAC

The SciDAC program within the High Energy Physics program supports the major computational efforts inherent in evaluating the predictions of theories of fundamental particles, in performing detailed and accurate simulations of complex accelerator designs, and in developing the software tools needed to store, retrieve and analyze the huge quantities of data generated by current and future experiments over widely-distributed networks. These activities will play a key role in understanding the significance of current and future precision measurements, in optimizing the design and operations of current and future accelerator facilities, and in performing the physics analysis from many current and future experiments. These activities also include the design and construction of parallel computers optimized for high energy physics problems, and the development of software to exploit them most efficiently. This program is a close collaboration between university- and laboratory-based research groups supported by the High Energy Physics and the Nuclear Physics programs of the DOE, by the DOE Advanced Scientific Computing Research program, and by the National Science Foundation.

Highlights

Recent accomplishments include:

- 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.

By its nature, progress in theoretical physics cannot be predicted in advance. Thus quantitative annual performance goals and targets are inappropriate for this subprogram. Nevertheless, there are some current major thrusts in theoretical physics that we expect to continue in FY 2004:

- LATTICE QCD. Quantum Chromodynamics (QCD) is a very successful theory that describes the strong interactions between quarks and gluons. Although the equations that define this theory are in principle exact, none of the analytical methods that are so successful elsewhere in theoretical physics are adequate to analyze it. The reason that QCD is so intractable is that it is a strongly-coupled gauge field theory. The lack of precision in current QCD calculations is now limiting the understanding of many experimental results. It has long been known that QCD can be analyzed to any desired precision by numerical methods, given enough computational power. Recent advances in numerical algorithms coupled with the ever-increasing performance of computing have now made a wide variety of QCD calculations feasible with relatively high precision (errors of a few percent). Some of the computational tools for this effort are provided through the SciDAC program, and there will be a major effort to fabricate the necessary computer hardware.

- NEUTRINO PHENOMENOLOGY. The accumulating evidence that neutrinos have mass raises a host of fundamental and timely questions: whether neutrinos might be their own anti-particles; whether there might be CP violation, or even CPT violation (the combination of CP-and Time-invariance violation), in the neutrino sector; the role of neutrinos in supernova explosions; and whether neutrinos might be the origin of the matter-antimatter asymmetry in the universe. In turn these questions have strong connections to astrophysics, cosmology, and other sectors of particle physics, so that new developments have wide-ranging impacts. New theories of neutrinos are being developed, and the active world-wide program of neutrino experiments can be expected to clarify this interesting domain of elementary particles.

- NEW IDEAS. Theoretical physicists are speculating on whether there might be additional space dimensions that are normally hidden from us. It is even possible that some of these dimensions and their consequences are accessible to experiment, perhaps manifesting themselves in the production of mini-black holes at the LHC. Perhaps they can explain the nature of dark matter, or dark energy, or even suggest new cosmologies explaining the history and evolution of the universe.

Funding Schedule

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Theoretical Research					
University Research	22,855	23,855	23,795	-60	-0.3%
National Laboratory Research........	13,999	14,112	13,762	-350	-2.5%
SciDAC……………………	4,919	4,410	4,600	+190	+4.3%
Other..	1,232	113	99	-14	-12.4%
Total, Theoretical Physics	43,005	42,490	42,256	-234	-0.6%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
University Research...	**22,855**	**23,855**	**23,795**

The university program consists of groups at approximately 75 colleges and universities doing theoretical physics research. These university groups develop new theoretical models and provide interpretations of existing experimental data; they identify where new physical principles may be required and determine how to confirm their presence, thereby providing guidance for new experiments; they develop new mathematical and computational methods for analyzing theoretical models; and they are deeply involved in the SciDAC activities described below. The university groups train graduate students and post-docs. University physicists in this theoretical research area often work in collaboration with other university and laboratory groups. University-based research efforts will be selected based on peer review.

In FY 2004, the university theory program will address problems across the full range of theoretical physics research. There is currently a “window of opportunity” to interpret and understand the exciting new physics results expected from the Fermilab Tevatron regarding the Higgs boson and supersymmetric particles and the SLAC B-factory experiments studying CP violation and the matter-antimatter asymmetry, as described in previous sections. To the extent possible, the detailed funding allocations will take into account the involvement of university based research groups in these targeted physics research activities.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
National Laboratory Research	**13,999**	**14,112**	**13,762**

The national laboratory research program consists of groups at several laboratories. The scientists in these groups pursue a research agenda quite like that pursued at universities. In addition, those at the laboratories are a general resource for the national research program. Through continuing interaction with a diverse set of experimental scientists, they provide a clear understanding of the significance of measurements from ongoing experiments. It is also through such discussions that they help to shape and develop the laboratory's experimental program. The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers.

In FY 2004, the laboratory theoretical research groups will address problems across the full range of theoretical physics research, including the analysis and interpretation of the new data expected from both the Tevatron Collider detectors, CDF and D-Zero, and the B-factory's detector, BaBar.

SciDAC	**4,919**	**4,410**	**4,600**

Following upon the successful completion and installation of the uniform software environment on both types of parallel computer platforms being developed for this program, in FY 2004 there will be two principal SciDAC efforts. The prototype computers developed the previous year will be run under the new software environment for the most urgently needed research computations. This will also be the year in which the bulk of the fabrication of the large QCDOC ("QCD On a Chip") computer at BNL is planned, building on the infrastructure of the dedicated QCD computing facilities provided by the Japanese for Relativistic Heavy Ion Collider (RHIC). In addition, further R&D will be undertaken on the optimization of commercial cluster computers for Fermilab (and, in Nuclear Physics, for Thomas Jefferson National Accelerator Facility). The goal of this R&D effort is to provide an efficient design for a large QCD computing cluster based on commercial components to address the hardware challenges of lattice QCD computing, as noted above. Both the customized and the commercial component approaches are viewed as important and useful in addressing the magnitude of the QCD computational problem; however, if both R&D efforts are successful, only the most cost-effective option will be pursued.

Other	**1,232**	**113**	**99**

This category includes funding for conferences, studies, and workshops, funding for research activities that have not yet completed peer review, and to respond to new and unexpected physics opportunities.

Total, Theoretical Physics	**43,005**	**42,490**	**42,256**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
University Research	
▪ An decrease of $60,000 is taken in order to provide support for maintaining high priority facility operations	-60
National Laboratory Research	
▪ An decrease of $350,000 is taken in order to provide support for maintaining high priority facility operations	-350
SciDAC	
▪ An increase of $190,000 for the SciDAC program to maintain its level of effort.	+190
Other	
▪ A decrease of $14,000 in other research activities.	-14
Total Funding Change, Theoretical Physics	**-234**

Advanced Technology R&D

Mission Supporting Goals and Measures

The Advanced Technology R&D (ATRD) subprogram has as its goals providing the scientific and technological base for the development of new and improved accelerators, storage rings, and detectors, which lead to more advanced capabilities to carry out the experimental part of the high energy particle physics research program. The resulting technologies also provide significant benefits to other science and technology fields that use particle beams or particle detectors.

Introduction

High Energy particle physics research remains now, and for the foreseeable future, strongly dependent on the use of high energy particle beams provided by charged particle accelerators and storage rings. The research demands beams of great intensities and particle detectors with both the sensitivity to see the rare events and the selectivity to pull the signals for such events out of a cacophony of background noise. Operating in the extreme domains essential for successful particle physics research demands very specialized technology that takes substantial time and expense to invent, design, build, maintain and upgrade. The R&D programs that support such technology development are unavoidably costly and long term.

Since few of the core technologies used in high energy physics research are directly marketable, industry has no motivation to develop the necessary expertise or to do the essential R&D. Consequently, the DOE HEP program has supported a very successful program of technology R&D that has ensured the availability of the most technically advanced research facilities and a world-class U.S. HEP Program.

The High Energy Physics Advisory Panel (HEPAP), consisting of leading members of the high energy physics community, provides advice to the Department of Energy and the National Science Foundation on a continuing basis regarding the direction and management of the national high energy physics research program. The recommendations of their 2002 long range planning report state in part:

We recommend that the highest priority of the U.S. program be a high-energy, high-luminosity electron-positron linear collider, wherever it is built in the world. This facility is the next major step in the field and should be designed, built and operated as a fully international effort.

and:

We recommend that vigorous long-term R&D aimed toward future high energy accelerators be carried out at high priority within our program.

The FY 2004 budget maintains a significant U.S. effort focused on Linear Collider R&D, consistent with the first HEPAP recommendation, and progress towards a truly international Linear Collider proposal will continue. However, the emphasis on exploiting current unique opportunities through operations of forefront HEP facilities in the U.S. precludes a positive response to the latter recommendation. In fact, most areas of accelerator and detector R&D decrease in FY 2004 in order to provide support for high-priority facility operations. Details are provided in the following sections.

The Advanced Technology Research and Development subprogram includes both R&D to bring new accelerator concepts to the stage where they can be considered for use in existing or new facilities (General Accelerator R&D), and advancement of the basic sciences underlying the technology (Accelerator Science). A third topic, Other Technology R&D, describes Advanced Detector Research and Detector Development. Most of the technology applications useful to other science programs flow from the work carried out in the Advanced Technology R&D subprogram.

Accelerator Science

The Accelerator Science category in the ATRD subprogram focuses on the science underlying the technologies used in accelerators and storage rings. There is an emphasis on future-oriented, high-risk R&D, particularly in the development of new accelerating concepts, but essential infrastructure to support the HEP technology R&D programs is also addressed. Examples of this include standards for testing of advanced superconducting materials, instrumentation standards, and user facilities for general support of accelerator research, such as the Accelerator Test Facility at BNL.

Accelerator Development

Discovery and proof of principle of new concepts are funded under Accelerator Science R&D, described above. The larger task of reducing new concepts and technical approaches to the stage of proven engineering feasibility, so that they can be incorporated into existing or new facilities, is done under Accelerator Development. When concepts develop enough to be viewed as part of a larger system or as leading to a possible future proposal for a construction project, they are given special attention. The Muon Accelerator/Neutrino Source and the Linear Collider, whose funding is included in this section of the budget, are the two current R&D activities in this special category.

Other Technology R&D

This category includes funding at universities under Advanced Detector Research and primarily at national laboratories under Detector Development. Advanced Detector Research is similar to Accelerator Science in that it addresses the development and application of the underlying science to new particle detection, measurement, and data processing technologies. The Detector Development program provides funding to national laboratories and some universities to bring new detection and data processing concepts to an engineering readiness state so that they can be incorporated into an existing detector or into a new experiment.

Highlights

Recent accomplishments include:

- Researchers continue to make major evolutionary progress in high field magnets for the next generation of both electron and hadron colliders. The critical current of high field Niobium-3-Tin superconductors continues to set new records in performance. Work at the national laboratories and at universities has shown interesting approaches in the fabrication of very high field accelerator magnets that address both the need for strain management within the windings and the handling of the brittle superconducting materials.

- Progress has been made on alternate methods of charged particle acceleration. In particular, it appears that this may be reduced to practice at SLAC in Experiment E187, the "afterburner." In this project the energy of the linac may be significantly increased by placing a plasma wakefield channel at the far end of the linac.

The major Advanced Technology research and development efforts in FY 2004 are:

- THE ACCELERATOR SCIENCE RESEARCH PROGRAM. This program supports studies in scientific topics such as laser and radiofrequency driven accelerating means, plasma-based accelerators, superconducting material development and applications, and nonlinear dynamics and chaos at some 27 universities and 6 DOE national laboratories (ANL, BNL, LANL, LBNL, PPPL, and SLAC). The programs of research at the universities and national laboratories are complementary and collaboration between the national laboratories and the university research groups is strongly encouraged.
- THE RESEARCH AND DEVELOPMENT PROGRAM IN GENERAL TECHNOLOGY R&D. A component of the technology R&D at BNL, Fermilab, LBNL, and SLAC is focused on "reduction of practice" of new ideas and in general areas of technology important to that laboratory, but not directly relevant to an operating facility or a new facility under construction. The principal activities funded are R&D on advanced superconducting magnets, radiofrequency acceleration systems, and new beam instrumentation.
- SUPPORT FOR LINEAR COLLIDER R&D. A TeV scale linear electron-positron collider has been identified by the international high energy particle physics community, including various national laboratories, international advisory committees, and the U.S. High Energy Physics Advisory Panel (HEPAP), as an essential international facility to extend particle physics research into precision measurements not feasible at the LHC. A U.S. National Collaboration, including SLAC, Fermilab, LBNL, LLNL, and BNL, is funded to develop new technologies that enable a higher performance, lower cost machine, focusing on systems engineering, value engineering and risk analysis studies of applicable technologies.

Subprogram Goal

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 (Advanced Technology R&D subprogram).

Performance Indicator

Demonstration of R&D milestones and prototype components.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Demonstrate that 50MV/m accelerating gradients in the Next Linear Collider (NLC) accelerating structures are sustainable without significant structural damage. *[Met Goal]*	Demonstrate operation of advanced design accelerating structure for the NLC at 70 MV/m.	Complete the full prototype test of the "8 pack" radio-frequency power source with the power compression system. This is the last major "proof-of-principle" system test for the NLC design.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Demonstrate operation of liquid mercury jet target hit by an intense proton beam as a first step in proving technology components for muon accelerators .*[Met Goal]*		Demonstrate operation of liquid mercury jet target hit by an intense proton beam in a strong (20 Tesla) magnetic field as a second step in proving technology for a muon accelerator source.
Continue R&D with industry to improve performance of superconducting cable; improve current-carrying capacity by 50% with respect to FY 2000. *[Met Goal]*	Begin engineering development program at LBNL and Fermilab for fabrication of prototype accelerator magnets with a goal of operating at fields greater than 16 Tesla. Begin industrial R&D program to develop large-scale capacity for producing high-performance Superconducting cable.	Produce 3-4 model magnets with selected key design parameters. Test and analyze performance.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Advanced Technology R&D					
Accelerator Science	17,892	19,905	20,836	+931	+4.7%
Accelerator Development	41,234	37,337	33,208	-4,129	-11.1%
Other Technology R&D................	8,388	14,082	9,919	-4,163	-29.6%
SBIR/STTR.................................	0	15,629	17,279	+1,650	+10.6%
Total, Advanced Technology R&D ..	67,514	86,953	81,242	-5,711	-6.6%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Accelerator Science..	**17,892**	**19,905**	**20,836**
▪ **University Research**	**8,796**	**9,701**	**9,401**

In FY 2004, funding will provide for a program of accelerator physics and related technologies at some 27 universities. The research program includes development of new applications of niobium-tin and similar superconductors as well as high temperature superconductors; investigations of the use of plasmas and lasers to accelerate charged particles; development of novel high power radio frequency sources for driving accelerators; development of advanced particle beam instrumentation; theoretical studies in advanced beam dynamics, including the study of non-linear optics; space-charge dominated beams and plasmas; and development of new computational and simulation methods and programs. The largest programs are at the University of Maryland and University of California, Los Angeles, but substantial activities are also supported at Stanford, Texas A&M and

	FY 2002	FY 2003	FY 2004

(dollars in thousands)

the University of Wisconsin. University based research programs are selected based on review by well-qualified peers, and progress is monitored through a system of formal site visits, presentations at appropriate workshops, and participation in conferences, and publications.

	FY 2002	FY 2003	FY 2004
▪ **National Laboratory Research**	**7,736**	**8,543**	**8,813**

There are areas of Accelerator Science research that require the more extensive or specialized research facilities located at DOE national laboratories. Funding for this work is provided to six national laboratories, ANL, BNL, LANL, LBNL, PPPL, and SLAC. National laboratory research efforts are selected based on review by appropriate peers, laboratory program advisory committees, and special director-appointed review committees. Measurement of progress is by these means, the annual HEP Program review supported by well-qualified peers, and publications in professional journals and participation in conferences and workshops.

BNL ($2,326,000) is the home of a very successful user facility, the Accelerator Test Facility (ATF), supporting research that HEP funds at universities and in industry (particularly through the SBIR Program). In FY 2004, the ATF will carry out an internal program of testing advanced accelerator concepts, developing new instrumentation, and developing next generation high brightness electron sources based on laser-driven photocathodes.

The Center for Beam Physics at LBNL ($3,663,000) is supported in FY 2004 for research in laser-driven plasma acceleration, advanced radiofrequency systems, laser manipulation and measurement of charged particle beams, and a broad program in acceleration theory and computation.

An advanced accelerator R&D program is supported at SLAC ($1,000,000) in FY 2004 to explore particle-driven plasma accelerators, direct laser acceleration, ultra high-frequency microwave systems for accelerating charged particles, very advanced electron-positron colliders concepts, and theoretical studies in advanced beam dynamics methods and new computer computation and simulation codes. Much of the work on advanced accelerator concepts at SLAC is done in collaboration with universities funded by the ATRD subprogram.

Other activities in FY 2004 include theoretical studies of space-charge dominated beams is supported at PPPL. At ANL the research addresses new means of generating high-brightness electron beams, and the use of charged particle wakefields to generate microwaves for particle acceleration. Maintenance and development of standard accelerator, storage ring, and beam optics computer codes is supported at the Accelerator Code Group at LANL, which also maintains an online encyclopedia of accelerator-related computer codes developed throughout the U.S.

	FY 2002	FY 2003	FY 2004
▪ **Other**	**1,360**	**1,661**	**2,622**

This category includes funding for Accelerator Science at sites other than universities and national laboratories. These include interagency agreements with NRL and NIST and funding of industrial grants. Also included is funding for Accelerator Science activities that are awaiting approval pending the completion of peer review and program office detailed planning.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Accelerator Development	**41,234**	**37,337**	**33,208**
▪ **General Accelerator Development**	**17,198**	**14,574**	**10,374**

This research includes R&D to bring new concepts to a stage of engineering readiness wherein they can be incorporated into existing facilities, used in upgrading existing facilities, or applied to the design of new facilities. The work is almost all done at BNL, Fermilab, LBNL and SLAC. The major areas of R&D are superconducting magnet and related materials technology, high-powered radiofrequency acceleration systems; instrumentation; stochastic and electron cooling technologies; beam dynamics, both linear and nonlinear; and development of large simulation programs. *In FY 2004 this general research area is significantly reduced in order to provide support for high-priority facility operations.* Progress in many of the areas listed above will be slowed, particularly those which do not have near-term impact on improvements or upgrades for those facilities.

Work at BNL in FY 2004 will focus on superconducting magnet R&D and related materials development. The R&D program at Fermilab in FY 2004 will address a broad spectrum of technology needs for that facility, including advanced superconducting magnet R&D, stochastic cooling for the antiproton source, electron cooling, advanced beam instrumentation, and simulation codes to provide improved modeling of all aspects of Tevatron operations. The LBNL R&D supported in FY 2004 includes work on very high field superconducting magnets using niobium-tin and possibly niobium-aluminum, on development of superconducting wire and cable for their magnet R&D, on new beam instrumentation for use at Fermilab and SLAC, and on an extensive beam dynamics and simulation studies program with particular emphasis on electron cloud and related efforts in proton and electron colliders. The FY 2004 program at SLAC encompasses high-powered radiofrequency systems, beam instrumentation, generic electron-positron collider R&D, and advanced beam dynamics and machine simulation code development. Simulation codes for modeling radiofrequency system components and high-powered microwave tubes will receive special R&D focus.

▪ **Linear Collider**	**19,200**	**19,200**	**19,200**

The need for an electron-positron linear collider as a complement to and precision augmentation of the research program that will be carried out at the LHC now under construction at CERN has been reviewed in the last year by the International Committee of Future Accelerators (ICFA), the European Committee on Future Accelerators (ECFA), and the Asian Committee on Future Accelerators (ACFA). These bodies all have identified a TeV scale linear collider as the highest priority facility following the LHC to address the broad range of physics questions about the standard model, the Higgs boson that is believed to give rise to mass, supersymmetry, and the postulated hidden dimensions of space itself.

The result of the international R&D Program is that there are now two principal, viable technical approaches to constructing a high energy linear collider. One of these approaches, developed by a collaboration led by the German high energy physics laboratory, Deutsches Elektronen-Synchrotron (DESY), is based on the use of a superconducting radiofrequency acceleration system cooled to approximately 452 degrees Fahrenheit below zero. DESY submitted a proposal to the German government in March of 2000 to build their project, called the TeV-Energy Superconducting Linear Accelerator (TESLA), at a site adjacent to the DESY site. The other approach, developed by a U.S.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

collaboration, led by SLAC and including Fermilab, LBNL and LLNL and in collaboration with the Japanese high energy physics laboratory, KEK, is developing a design based on room temperature radiofrequency accelerating system similar in principle to the one used in the SLAC Linear Collider. This R&D project is called the "Next Linear Collider" (NLC). All funding in this budget category is directed towards NLC-related R&D.

In FY 2004, the Next Linear Collider Collaboration will continue the systems engineering, value engineering, risk analysis, and cost studies that have been used to guide the R&D. A particular focus will be on assembly and operation of the so-called "Eight Pack Test." This will be a demonstration of a complete radiofrequency accelerating module for the NLC, including power supply, eight klystron tubes, pulse compressor, and the 70 MeV per meter accelerating structure needed to produce the 0.5 TeV on 0.5 TeV electron-positron colliding beams that give a 1 TeV center-of-mass energy. In addition work will continue with KEK on the injection damping ring technology using the prototype ring built at KEK and on design of the electron and positron sources and final focus beam optics systems. A U.S. national collaboration was formed in 2002 to begin developing a physics research agenda and to begin advanced R&D on technologies to be used in a linear collider detector with which to carry out the physics studies.

▪ **Muon Accelerators/Neutrino Source**...........................	**4,836**	**3,563**	**3,634**

The technical requirements for a muon accelerator/neutrino source force the consideration of new technologies that do not yet exist. The three principal areas are ultra high intensity muon targets, transverse and longitudinal phase space cooling (to reduce beam size), and special high-powered but low-frequency accelerating structures. The latter are especially important for capturing the muon bunches from the target and rapidly accelerating them to high energy so as to take advantage of the relativistic time dilation that lengthens the muon decay time so the short-lived muons survive long enough to store.

In FY 2004, the major focus of the research will be on completing the muon production target feasibility studies at the BNL AGS and on preparing to participate in the Muon International Cooling Experiment (MICE) to test the concept of ionization cooling of transverse phase space. System studies looking for alternate technologies, particularly radiofrequency systems, will continue as will studies of conventional and superconductor radiofrequency cavities operating in the special environment that allows the acceleration and cooling of the muon beams to be superimposed.

Other Technology R&D...	**8,388**	**14,082**	**9,919**
▪ **Advanced Detector Research**..	**461**	**0**	**500**

The Advanced Detector Research (ADR) program supports university physicists to develop new detector technologies. The chosen technologies are motivated by the needs of foreseen but not yet approved experiments. Approximately six to eight grants a year are awarded through a competitive peer review program. This program complements the detector development programs of the national laboratories.

	(dollars in thousands) FY 2002	FY 2003	FY 2004
▪ **Detector Development**	**7,921**	**11,773**	**8,993**

New experiments frequently depend on advancements in technologies. This funding supports detector development work at the national laboratories to advance these technologies to a point where there is reasonable chance that an experiment can adopt the technology successfully. Technology choices are based on the needs of foreseen experiments. In FY 2004, this research area is also significantly reduced in order to meet high-priority needs for facility operations.

	FY 2002	FY 2003	FY 2004
▪ **Other**	**6**	**2,309**	**426**

This category includes funding for conferences, studies, and workshops, funding for research activities that have not yet completed peer review, and to respond to new and unexpected physics opportunities.

	FY 2002	FY 2003	FY 2004
SBIR/STTR	**0**	**15,629**	**17,279**

The two activities funded are the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) set asides mandated by Congress. The High Energy Physics Program runs four technical topics related to accelerator science and technology and two topics related to detector science and technology in the annual procurement solicitation. The contents of each topic are closely related to the R&D work funded in Advanced Technology, and consist of material provided in response to an annual HEP solicitation for suggestions from scientists and engineers working in support of the HEP Advanced Technology R&D programs. In FY 2002, $14,521,000 was transferred to the SBIR program and $871,000 was transferred to the STTR program.

	FY 2002	FY 2003	FY 2004
Total, Advanced Technology R&D	**67,514**	**86,953**	**81,242**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Accelerator Science	
▪ An increase of $931,000 provides support for long-term R&D efforts focused on developing new particle acceleration techniques.	+931
Accelerator Development	
▪ A decrease of $4,200,000 in General Accelerator R&D, reducing effort in near-term R&D and “reduction to practice” is taken in order to maintain support for high-priority facility operations. This is slightly offset by an increase of $71,000 provided to the Muon Accelerators/Neutrino Source R&D program to continue progress towards two key experiments that are needed to demonstrate the feasibility of the muon accelerator concept.	-4,129

	FY 2004 vs. FY 2003 ($000)
Other Technology R&D	
▪ A decrease of $2,780,000 is taken in Detector Development, reducing R&D efforts on future experiments, in order to maintain support for high-priority facility operations. A net decrease of $1,383,000 is taken in funds held pending completion of peer review and/or program considerations.	-4,163
SBIR/STTR	
▪ An increase of $1,650,000 for the SBIR and STTR programs.	+1,650
Total Funding Change, Advanced Technology R&D	**-5,711**

Construction

Mission Supporting Goals and Measures

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 2002	FY 2003	FY 2004	$ Change	% Change
Neutrinos at the Main Injector...........	11,400	20,093	12,500	-7,593	-37.8%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Neutrinos at the Main Injector (NuMI)	**11,400**	**20,093**	**12,500**

This project provides for the construction of new facilities at Fermilab that are specially designed for the study of the properties of the neutrino and in particular to search for neutrino oscillations. The FY 2004 funding is for construction and installation of the neutrino beam line in the underground tunnel. The project is proceeding well within the schedule and cost baselines established with the FY 2003 request.

Performance will be measured by accomplishment of scheduled milestones as detailed in the revised benchmark plan.

	FY 2002	FY 2003	FY 2004
Total, Construction	**11,400**	**20,093**	**12,500**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Neutrinos at the Main Injector (NuMI)	
▪ Funding needs decrease as project nears completion in FY 2005. Sufficient funds provided for completion of the Fermilab NuMI project on the current approved profile.	-7,593
Total Funding Change, Construction	**-7,593**

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
General Plant Projects	9,569	12,500	12,500	0	0.0%
Accelerator Improvements Projects	10,835	18,790	15,170	-3,620	-19.3%
Capital Equipment	82,177	85,313	80,708	-4,905	-5.7%
Total, Capital Operating Expenses	102,581	116,603	108,378	-8,225	-7.1%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2002	FY 2003	FY 2004	Unapprop-riated Balance
98-G-304 Neutrinos at the Main Injector	109,242	64,749	11,400	20,093	12,500	500

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2002	FY 2003	FY 2004 Request	Accept-ance Date
Large Hadron Collider — Machine	85,672	64,506	8,196	6,850	4,300	FY 2005
Large Hadron Collider — ATLAS Detector[a]	54,099	26,756	7,642	10,134	4,710	FY 2008
Large Hadron Collider — CMS Detector	67,051	41,905	6,000	9,484	3,930	FY 2008
MINOS	44,510	21,245	15,275	5,490	2,000	FY 2005
GLAST/LAT	37,000	8,689	8,080	8,910	7,900	FY 2005
Cryogenic Dark Matter Search (CDMS)	4,918	2,598	970	800	550	FY 2004
Auger[b]	3,250	0	1,000	1,250	1,000	FY 2004
Alpha Magnetic Spectrometer (AMS) Upgrade	4,756	2,228	1,778	750	0	FY 2003
Run IIb D-Zero Detector[c]	20,621	0	3,460	7,500	8,588	FY 2006
Run IIb CDF Detector[c]	24,987	0	3,460	7,500	8,396	FY 2006
VERITAS	4,799	0	0	0	1,600	FY 2006
Total, Major Items of Equipment		167,927	55,861	58,668	42,974	

[a] At the end of FY 2005 approximately 97% of the U.S. CMS and U.S. ATLAS projects will be completed on schedule. The remaining 3% of the project scope is integrally connected to the CERN portion of the project. As such, the recent slip in the CERN project schedule will significantly impact our ability to complete the remaining 3% of this project on the present schedule. The 97% portion of this project that will be complete at the end of FY 2005 will be closed out at that time. The remaining 3% of the project will continue, consistent with all DOE project management policies and practices. Based on CERN's current schedule, it is anticipated that the remaining work will be completed by the end of FY 2008, with no change in the total estimated cost of the project.

[b] The TEC for this project has been revised with an addition of funds in FY 2004 in anticipation of additional U.S. efforts being undertaken at that time.

[c] The TEC for this project is based on the estimate developed late in 2002 as part of a baseline readiness review, including the complete conceptual design and the latest machine performance information. This estimate will be updated further and finalized in Spring of 2003, upon completion of Title I design. The funding profile shown is still preliminary, based on FY 2002 actual expenditures and the FY 2003 President's Budget.

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

(Changes from FY 2003 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		
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
FY 2004 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	21,489
2003	20,093	20,093	24,000
2004	12,500	12,500	14,000
2005	500	500	7,926

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 Main Injector accelerator at the MI-60 extraction region. The beam components will be installed in a new tunnel of approximately 1.5 km in length and 6.5 m diameter. The beam is aimed at two detectors (MINOS), which will be assembled in two new 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 FY 2004 funding is for construction and installation of the neutrino beam line in the underground tunnel.

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	12,265	12,228
Special Equipment	20,902	20,902
Other Structures	40,184	41,265
Construction Management (8.6% of TEC)	9,379	6,846
Project Management (4.1% of TEC)	4,430	4,788
Total, Construction Costs	87,160	86,029
Contingencies		
Construction Phase (13.6% of TEC)	14,902	16,033
Total, Contingencies (13.6% of TEC)	14,902	16,033
Total, Line Item Cost (TEC)	109,242	109,242

5. Method of Performance

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

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

6. Schedule of Project Funding

(dollars in thousands)

	Prior Years	FY 2002	FY 2003	FY 2004	Outyears	Total
Project Cost						
Facility Cost						
Total, Line item TEC	41,827	21,489	24,000	14,000	7,926	109,242
Other Project Costs						
Capital equipment [a]	17,198	14,216	9,443	2,000	1,653	44,510
R&D necessary to complete construction[b]	1,768	0	0	0	0	1,768
Conceptual design cost[c]	1,928	0	0	0	0	1,928
Other project-related costs[d]	10,045	1,783	983	800	383	13,994
Total, Other Project Costs	30,939	15,999	10,426	2,800	2,036	62,200
Total Project Cost (TPC)	72,766	37,488	34,426	16,800	9,962	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. Prior year totals have been adjusted to more accurately account for actual R&D costs.

[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. Prior year totals have been adjusted to more accurately account for actual conceptual design costs.

[d] Includes funding required to complete the construction and outfitting of the Soudan Laboratory for the new far detector by the University of Minnesota. In particular, includes $9,301,000 in prior years and $1,468,000 in FY 2002 for capital costs of cavern construction; remainder is operating expenses related to the construction of the cavern and the MINOS detector. Prior year totals have been adjusted to more accurately account for actual other project-related costs.

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 2005 through FY 2010)*	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 2004.

Nuclear Physics

Program Mission

The mission of the Nuclear Physics 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 Department of Energy'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 Nuclear Physics mission areas under the mandate provided in Public Law 95-91 that established the Department.

Overview:

Nuclear science began by studying the structure and properties of atomic nuclei as assemblages of protons and neutrons. Research focused on nuclear reactions, the nature of radioactivity, and the synthesis of new isotopes and new elements heavier than uranium. Great benefit, especially to medicine, emerged from these efforts. But today, nuclear science is much more than this. Today, its reach extends from the quarks and gluons that form the substructure of the once-elementary protons and neutrons, to the most dramatic of cosmic events—supernovae. At its heart, nuclear physics attempts to understand the composition, structure, and properties of atomic nuclei. The field is driven by the following broad questions as stated recently by the Nuclear Sciences Advisory Committee in the ***Opportunities in Nuclear Science: A Long-Range Plan for the Next Decade***.

- *What is the structure of the nucleon?* Protons and neutrons are the building blocks of nuclei and neutron stars. But these nucleons are themselves composite objects having a rich internal structure. Connecting the observed properties of the nucleons with an underlying theoretical framework, known as quantum chromodynamics (QCD), is one of the central goals of modern nuclear physics.
- *What is the structure of nucleonic matter?* Nuclear physics strives to explain the properties of nuclei and of nuclear matter. The coming decade will focus especially on unstable nuclei, where we expect to find new phenomena and new structure unlike anything known from the stable nuclei of the world around us. With new theoretical tools, we hope to build a bridge between the fundamental theory of strong interactions and the quantitative description of nuclear many-body phenomena, including the new and exotic properties we expect in unstable nuclei and in neutron stars.
- *What are the properties of hot nuclear matter?* The quarks and gluons that compose each proton and neutron are normally confined within the nucleon. However, QCD predicts that, if an entire nucleus is heated sufficiently, individual nucleons will lose their identities, the quarks and gluons will become "deconfined," and the system will behave as a plasma of quarks and gluons. With the Relativistic Heavy Ion Collider (RHIC), the field's newest accelerator, nuclear physicists are now hunting for this new state of matter.

Other major questions identified by NSAC, of equal importance for nuclear physics as those above, overlap with major questions that drive the fields of astrophysics and particle physics. These are:

- *What is the nuclear microphysics of the universe?* A great many important problems in astrophysics—the origin of the elements; the structure and cooling of neutron stars; the origin, propagation, and interactions of the highest-energy cosmic rays; the mechanism of core-collapse supernovae and the associated neutrino physics; galactic and extragalactic gamma-ray sources—involve fundamental nuclear physics issues. The partnership between nuclear physics and astrophysics will become ever more crucial in the coming decade, as data from astronomy's "great observatories" extend our knowledge of the cosmos.
- *What is to be the new Standard Model?* The resolution of the solar and atmospheric neutrino puzzles by the Sudbury Neutrino Observatory (SNO) and the SuperKamiokande Detector may require the addition of Super-Symmetry to the Standard Model. Precision experiments by nuclear physicists deep underground and at low energies are proving to be an essential complement to searches for new physics in high-energy accelerator experiments.

How We Work:

The Nuclear Physics program uses a variety of mechanisms for conducting, coordinating, and funding nuclear physics research. The program is responsible for planning and prioritizing all aspects of supported research, conducting ongoing assessments to ensure a comprehensive and balanced portfolio, regularly seeking advice from stakeholders, supporting core university and national laboratory programs, and maintaining a strong infrastructure to support nuclear physics research.

Advisory and Consultative Activities:

To ensure that resources are allocated to the most scientifically promising research, the Department of Energy and its national user facilities actively seek external input using a variety of advisory bodies. The Nuclear Physics research program needs to produce the scientific knowledge, technologies and trained manpower that underpin the Department's missions in national security, energy, and environmental quality.

The ***Nuclear Sciences Advisory Committee*** (NSAC) provides advice to the Department of Energy and the National Science Foundation on a continuing basis regarding the direction and management of the national basic nuclear sciences research program. In FY 2002, the DOE Nuclear Physics program provided about 90% of the federal support for fundamental nuclear physics research in the nation. The National Science Foundation (NSF) provided most of the remaining support. NSAC regularly conducts reviews of the operations of individual university and national laboratory facilities to assess their scientific productivity, major components of the Division's research program, and evaluates the scientific case for new facilities. One of the most important functions of NSAC is development of long-range plans that express community-wide priorities for the upcoming decade of nuclear physics research.

Facility directors seek advice from ***Program Advisory Committees*** (PACs) to determine the allocation of scarce scientific resources – the available beam time. The committees comprise members mostly external to the host lab who are appointed by the director. PACs review research proposals requesting time at the facilities and technical resources; they provide advice on a proposal's scientific merit, technical feasibility, and manpower requirements. The PAC also provides a recommendation for the proposal to be approved, conditionally approved, deferred, or rejected.

Facility Operations Reviews:

The Nuclear Physics program has undertaken a series of operations reviews of its two largest national user facilities: Relativistic Heavy Ion Collider (RHIC) and Continuous Electron Beam Accelerator Facility (CEBAF). Conducted by the Office of Science's Construction Management Support Division, these reviews enlisted experts from DOE National Laboratories and NSF-supported university nuclear physics facilities to evaluate present performance and costs of operations. The Division has also conducted an operations review of the Holifield Radioactive Ion Beam Facility (HRIBF) using similar external experts. Annual reviews of the RHIC and CEBAF programs with external reviewers are conducted to access the performance and scientific productivity of the facility.

Program Reviews:

NSAC, on a rotating schedule, reviews the major elements of the nuclear physics program. These reviews examine scientific progress in each program element against the previous long-range plan, assess the scientific opportunities, and recommend reordering of priorities based upon existing budget profiles. In 1998, the Medium Energy program was reviewed. In 2001, the Low Energy program was reviewed. Results of these reviews are discussed later in the context of the requests for the Medium Energy and Low Energy physics programs. Continuing the cycle of reviews, it is planned that the Theory and Heavy Ion programs will be reviewed. Quality and productivity of university grants and laboratory groups performing research are peer reviewed on an approximately three-year basis.

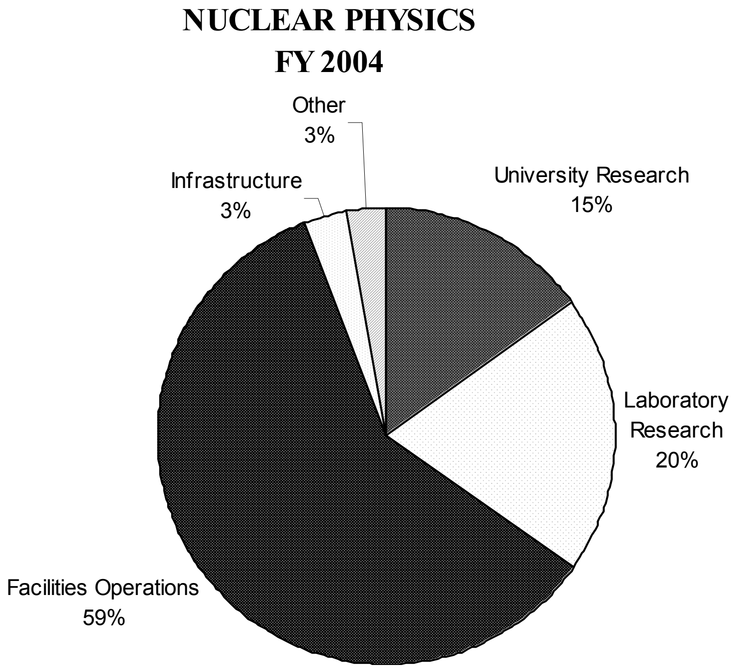
Planning and Priority Setting:

One of the most important activities of NSAC is the development of long-range plans that serve as a framework for the coordinated advancement of the field for the coming decade. These plans are undertaken every 5-6 years to review the scientific opportunities in the field, perform retrospective assessments of the major accomplishments by the field, and set priorities for the future. NSAC has identified increased support for the operations of the recently completed facilities as one of the highest priorities for DOE's Nuclear Physics program, as well as increased support for Nuclear Theory and computation. In the President's FY 2004 budget, funding supports operations at the newer major nuclear physics scientific user facilities. Operations are terminated at the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory as a nuclear physics user facility in order to provide enhanced support for the remaining Low Energy user facilities and to make investments in instruments and to enhance capabilities. Theory support is enhanced and experimental research efforts are maintained at FY 2003 levels to collect and analyze data, at the operating facilities. The long-range plan also identifies the Rare Isotope Accelerator (RIA) as the highest priority for major new construction; the President's FY 2004 budget requests continuing funding of $3.5 million for RIA R&D.

How We Spend Our Budget:

The Nuclear Physics budget has three major components: research, facility operations and experimental support, and construction and laboratory infrastructure support. The FY 2004 budget request is focused on optimizing the utilization of its major user facilities and increasing the support for Nuclear Theory. Facility operations are provided a 1.1% increase in funding in FY 2004 that will result in a 5% increase in beam hours for research compared to FY 2003. With the completion of RHIC construction in FY 1999, no major nuclear physics projects are under construction.

Research:



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 Nuclear Physics 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. Funding for university and national laboratory research (excluding capital equipment) is increased about 4.2% compared to FY 2003, providing a small restoration to the recent erosion of effort. National laboratory research scientists work together with the experimental collaborations to collect and analyze data as well as support and maintain the detectors. The laboratories provide state-of-the-art resources for detector and accelerator R&D for future upgrades and new facilities. The division of support between national laboratories and universities is adjusted to maximize scientific productivity.

- ***University Research***: University researchers play a critical role in the nation's research effort and in the training of graduate students. During FY 2002, the DOE Nuclear Physics program supported approximately two-thirds of the nation's university researchers and graduate students doing fundamental nuclear physics research. Among the 85 academic institutions DOE supports researchers in five university laboratories with local accelerators (Texas A&M Cyclotron Laboratory, Triangle Universities Nuclear Laboratory (TUNL) at Duke University, MIT Laboratory for Nuclear Science, University of Washington, and Yale University). DOE also supports the Institute for Nuclear Theory at the University of Washington. Typically about 90 Ph.D. degrees are granted annually to students for research supported by the program. One-half of those who received nuclear science Ph.D.'s between 1980 and 1994 are pursuing careers outside universities or national labs in such diverse areas as nuclear medicine, medical physics, space exploration, and national security.

  The university grants program is proposal driven, in much the same way as is the nuclear physics program at the NSF. The Nuclear Physics program funds the best and brightest of those ideas submitted in response to grant solicitation notices (see http://www.sc.doe.gov/production/grants/grants.html). Proposals are reviewed by external scientific peers and competitively awarded according to the guidelines published in 10 CFR 605.

- ***National Laboratory Research***: The Nuclear Physics program supports National Laboratory-based research groups at Argonne, Brookhaven, Jefferson, Los Alamos, Lawrence Berkeley, Lawrence Livermore, and Oak Ridge National Laboratories. The directions of laboratory research programs are driven by the needs of the Department and are highly tailored to the major scientific facilities at the laboratories. Laboratory researchers collaborate with academic users of the facilities and are important for developing and maintaining the large experimental detectors and computing facilities for data analysis. At the weapons laboratories, Nuclear Physics program funding plays an important role in supporting basic research that can improve the applied programs, such as proton radiography, neutron-capture reaction rates, properties of radioactive nuclei, etc.

The Nuclear Physics program funds field work proposals from the National Laboratories. Proposals are reviewed by external scientific peers and awarded according to a modified version of the 10 CFR 605 guidelines used for the grants program. Performance of the laboratory groups is reviewed every year to examine the quality of their research and identify needed changes, corrective actions or redirection of effort. Individual laboratory groups have special capabilities or access to laboratory resources that can be profitably utilized in the development of the scientific program.

Nuclear physics has made important contributions to our knowledge about the natural universe and has had great impact on human life. Knowledge and techniques developed in pursuit of fundamental nuclear physics research are extensively utilized in our society today. The understanding of nuclear spin enabled the development of magnetic resonance imaging for medical use. Radioactive isotopes produced by accelerators are used for medical imaging, cancer therapy, and biochemical studies. Particle beams are used for cancer therapy and in a broad range of materials science studies. Advances in cutting-edge instrumentation developed for nuclear physics experiments, such as high-resolution gamma ray detectors, have relevance to technological needs in combating terrorism.

The DOE Nuclear Physics program focuses its scientific thrusts along the high priority nuclear science questions identified by NSAC. To most effectively address these topics, the Nuclear Physics program is structured into four subprograms: the Medium Energy Nuclear Physics subprogram seeks to understand the structure of the nucleon; the Heavy Ion Nuclear Physics subprogram studies the properties of hot nuclear matter; the Low Energy Nuclear Physics subprogram focuses on the structure of nucleonic matter, the nuclear microphysics of the universe and addresses the possibility of new physics beyond the Standard Model; the Nuclear Theory subprogram provides the fundamental theories, models and computational techniques to address these science topics.

Program Strategic Performance Goals

SC2-1: Manage a productive and sustainable program that provides world-class research results in the scientific disciplines encompassed by the Nuclear Physics mission areas cognizant of DOE needs as well as the needs of the broad scientific community. (Medium Energy Nuclear Physics, Heavy Ion Nuclear Physics, Low Energy Nuclear Physics and Nuclear Theory subprograms)

Performance Indicators

Validation of results by merit review with external peer evaluation; validation of program directions by Nuclear Science Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
		At least 80% of all new research projects will be peer reviewed and deemed excellent (of highest quality) and relevant, and annually 30% of all ongoing projects will be subject to peer review with merit evaluation. (SC2-1-1) Respond to priorities and recommendations for the DOE Nuclear Physics program in the 2002 Nuclear Science Advisory Committee Long Range Plan: • increase support for research and operations in order to exploit the opportunities made possible by recent investments at the new and upgraded facilities, for university research and infrastructure, and for nuclear theory; • maintain support for R&D activities to prepare for the future construction of the possible major new facility, the Rare Isotope Accelerator (RIA); • maintain R&D funding and prepare for the upgrade of the Continuous Electron Beam Accelerator Facility at Jefferson Lab to 12 GeV. (SC2-1-2)

SC7-2: Manage all Nuclear Physics 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.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
Maintain and operate Nuclear Physics scientific user facilities so the unscheduled operational downtime will be kept to less than 20%, on average, of total scheduled operating time. (SC7-2-1) [Met Goal]	Maintain and operate Nuclear Physics scientific user facilities so the unscheduled operational downtime will be kept to less than 20%, on average, of total scheduled operating time. (SC7-2-1)	Maintain and operate Nuclear Physics scientific user facilities so the unscheduled operational downtime will be kept to less than 20%, on average, of total scheduled operating time. (SC7-2-1)

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
		Conduct annual reviews of the Thomas Jefferson National Accelerator Facility and the Relativistic Heavy Ion Collider facility; use results of reviews to identify areas where increased efficiency and scientific productivity can be obtained. (SC7-2-2)
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). (SC7-2-3)	Upgrade the RHIC cryogenics system by replacing turbine oil skids and removing seal gas compressor, eliminating a single point failure. (SC7-2-3)	
Meet the cost and schedule milestones for the PHENIX Muon Arm Instrumentation (Major Item of Equipment) within 10% of baseline estimates. (SC7-2-4) [Met Goal]	Meet the cost and schedule milestones for the construction of facilities and Major Items of Equipment within 10% of baseline estimates. Complete the Solenoidal Tracker at RHIC (STAR) Electro-Magnetic Calorimeter (EMCAL). (SC7-2-4)	Fabrication of the STAR EMCAL Enhancement, the Fundamental Neutron Physics Beamline at the Spallation Neutron Source, and the Gamma-Ray Energy-Tracking In-beam Nuclear Array (GRETINA) (Major Items of Equipment) will not exceed 10% of cost and schedule baseline estimates. (SC7-2-4)

Program Assessment Rating Tool (PART) Assessment

The Nuclear Physics program was evaluated with the OMB Program Assessment Rating Tool (PART). It was found that, "The program received a perfect score in the purpose section and a high score in the management section, mainly as a result of standard management practices within the Office of Science that lead the Nuclear Physics program to have a well defined mission, merit-based reviews for awarding contracts and grants, and highly-regarded large project management practices. The primary cause for the lower scores for planning and results is the program's current lack of adequate long-term and annual performance measures. Nevertheless, the program has made significant strides toward developing such measures despite the problems inherent in measuring and then predicting scientific progress." Other findings include, "The program is well-managed with a strong focus on training nuclear scientists and utilizing existing facilities in order to maximize scientific results," and, "The program coordinates its research strategy with the National Science Foundation through a jointly sponsored advisory committee (NSAC); however, the program does not yet have regular reviews of its research portfolio and processes by ad hoc panels composed of outside experts external to its advisory committee."

To address these findings, 1) The Nuclear Physics program will work with OMB to improve the performance goals and measures for the FY 2005 Budget request utilizing the Research and Development Investment Criteria developed by OMB; 2) Towards maximizing scientific productivity the FY 2004 Budget request provides funds to operate the program's user facilities at 83 percent of maximum capacity (compared with 80 percent in FY 2003 and 72 percent in FY 2002), while ceasing operations at one of its smaller user facilities; and 3) The Nuclear Physics program will institute a formal committee of visitors process by September, 2003.

Significant Program Shifts

In the FY 2004 budget request the scientific scope of the nation's nuclear physics program is maintained. The FY 2004 budget request terminates operations of one of the program's productive user facilities (the LBNL 88-Inch Cyclotron) in order to provide resources to optimize the utilization and science productivity of the remaining user facilities (BNL/RHIC, TJNAF/CEBAF, MIT/Bates Linear Accelerator Center, ANL/ATLAS, and ORNL/HRIBF). Facility operations at the remaining five facilities are provided a 2.7% increase in funding in FY 2004 that will result in a 29% increase in beam hours for research at these five facilities compared to FY 2003, (but only a 5% increase in beam hours overall because of the termination of the 88-Inch Cyclotron operation). 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 scientific productivity of the facilities. Funding for university and national laboratory research is increased about 4.2% compared to FY 2003, maintaining approximately constant effort for experimental efforts and enhancing theory efforts. Support for theory groups at the National Laboratories has been increased significantly at BNL, TJNAF, and ANL, by reallocation of some experimental support funds. The necessity for this increased support was identified in the 2002 NSAC Long Range Plan and is critical for the interpretation of the extensive new data coming from RHIC and TJNAF. Recognizing the exciting developments in research at the interface of nuclear physics and astronomy, the program increases support for non-accelerator-based research in the Low Energy subprogram. Funding for capital equipment will address opportunities identified in the recently completed 2002 NSAC Long Range Plan, while R&D activities for RIA are kept constant.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) activity is a set of coordinated investments across all Office of Science mission areas with the goal to achieve breakthrough scientific advances through computer simulation that were impossible using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. By exploiting advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-discipline collaboration among the scientific disciplines, computer scientists and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can fully exploit terascale computing and networking resources. The program will bring simulation to a parity level with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate prediction, plasma physics, particle physics, astrophysics and computational chemistry.

Scientific Facilities Utilization

The Nuclear Physics request for FY 2004 supports the Department's scientific user facilities. In FY 2002 Nuclear Physics operated seven National User Facilities, which provide research time for scientists in universities and other Federal laboratories. In FY 2003 the program supports operations at:

- The Relativistic Heavy Ion Collider (RHIC) complex and the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory. (The AGS is not operating in FY 2003 and FY 2004 for Nuclear Physics.);
- The Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility;

- The Bates Linear Accelerator Center at Massachusetts Institute of Technology;
- The Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory;
- The Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory; and
- The 88-Inch Cyclotron at Lawrence Berkeley National Laboratory. (The 88-Inch Cyclotron terminates operation in FY 2004.)

These facilities provide beams for research for a user community of about 2,400 scientists. The FY 2004 President's Budget Request will support operations of five facilities that will provide ~21,760 hours of beams for research, an increase of ~5% over the anticipated beam hours in FY 2003.

Nuclear Physics will maintain and operate its major scientific user facilities so that the unscheduled operational downtime will be kept to less than 20%, on average, of total scheduled operating time.

(hours)	FY 2000	FY 2001	FY 2002	FY 2003 Request	FY 2004 Request
Number of Facilities	7	7	7	6	5
Maximum Hours	31,500	31,600	31,600	32,275	26,260
Planned Operating Hours	23,150	20,285	17,510	20,700	21,760
Achieved Operating Hours	19,365	24,575	26,750	–	–
Unscheduled Downtime – Major user facilities	18%	18%	13%	–	–
Number of Users*	2,976	3,020	2,440	2,355	2,230

* Due to use of multiple facilities some users may be multiple counted.

In FY 2002, the achieved operating hours have well exceeded the planned operating hours for several reasons: increased operation of the Alternate Gradient Synchrotron for the Medium Energy program in order to finish experiments prior to termination of operations for this program, doubling the running hours of the MIT/Bates Electron Linear Accelerator to allow completion of the SAMPLE experiment prior to shutdown of this facility, and significantly increased operation of Low Energy facilities to take advantage of scientific opportunities by deferring maintenance.

Nuclear Physics will meet the cost and schedule milestones for construction of facilities and fabrication of Major Items of Equipment (MIE) within 10% of baseline estimates. Earned-value tracking is not maintained for MIE projects under $20,000,000; however, quarterly progress reviews are used to help ensure that projects remain on track.

Construction and Infrastructure:

Funding for capital equipment is reduced by ~5% compared to FY 2003 and R&D activities directed at RIA are kept constant. The Nuclear Physics program as part of its responsibilities as the landlord for Brookhaven National Laboratory and Thomas Jefferson National Accelerator Facility (TJNAF) provides funding for general plant projects (GPP) to both sites and general purpose equipment (GPE) to BNL only.

Workforce Development

The Nuclear Physics program supports development of the Research and Development (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, security 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, and national security. The Outstanding Junior Investigator (OJI) program, initiated in FY 2000, through ~5 new awards each year, has been very successful in identifying, recognizing, and supporting promising young faculty. About 800 postdoctoral research associates and graduate students supported by the Nuclear Physics program in FY 2002 were involved in a large variety of experimental and theoretical research projects. About 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. The FY 2004 funding level will support approximately the same number of postdoctoral research associates and graduate students as supported in FY 2003. Details of the DOE nuclear physics human capital are given below. In FY 2002 there were about 302 faculty researchers supported at the universities (~1.7 per grant), with an average award of ~$183,000 per faculty researcher. Almost all grants have a duration of three years.

	FY 2000	FY 2001	FY 2002	FY 2003, est.	FY 2004, est.
# University Grants*	171	180	181	185	185
Average size (excl. CE)	$314,000	$310,000	$306,000	$294,000	$307,000
# Lab groups	27	28	28	28	28
# Permanent Ph.D.'s	676	683	702	700	700
# Postdocs	363	362	364	360	360
# Graduate students	408	408	442	440	440
# Ph.D.'s awarded	87	67	100	~90	~90

*Tasks in multitask grants to university laboratories are counted separately.

Funding Profile

(dollars in thousands)

	FY 2002 Comparable Appropriation	FY 2003 Request	FY 2004 Request	$ Change	% Change
Nuclear Physics					
Medium Energy Nuclear Physics ..	111,218	123,590	124,198	+608	+0.5%
Heavy Ion Nuclear Physics	151,273	167,977	167,805	-172	-0.1%
Low Energy Nuclear Physics	62,769	66,158	69,289	+3,131	+4.7%
Nuclear Theory..............................	25,329	24,645	28,138	+3,493	+14.2%
Total, Nuclear Physics	350,589 [a] [b]	382,370	389,430	+7,060	+1.8%

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 $7,777,000 that has been transferred to the SBIR program and $467,000 that has been transferred to the STTR program.

[b] Excludes $202,000 for the FY 2002 rescission contained in Section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to Terrorist attacks on the United States.

Funding by Site [a]

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	9,652	9,123	9,104	-19	-0.2%
Chicago Operations Office					
Argonne National Laboratory	18,453	17,548	18,709	+1,161	+6.6%
Brookhaven National Laboratory	140,108	149,004	149,588	+584	+0.4%
Fermi National Accelerator Laboratory	231	0	0	0	--
Chicago Operations Office	53,029	52,111	52,655	+544	+1.0%
Total, Chicago Operations Office	211,821	218,663	220,952	+2,289	+1.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	19,943	18,615	15,840	-2,775	-14.9%
Lawrence Livermore National Laboratory	664	507	700	+193	+38.1%
Oakland Operations Office	16,682	16,278	16,258	-20	-0.1%
Total, Oakland Operations Office	37,289	35,400	32,798	-2,602	-7.4%
Oak Ridge Operations Office					
Oak Ridge Institute for Science & Education	607	189	194	+5	+2.6%
Oak Ridge National Laboratory	15,974	16,870	19,330	+2,460	+14.6%
Thomas Jefferson National Accelerator Facility	74,761	79,138	82,247	+3,109	+3.9%
Total, Oak Ridge Operations Office	91,342	96,197	101,771	+5,574	+5.8%
Richland Operations Office					
Pacific Northwest National Laboratory	20	0	0	0	--
Washington Headquarters	465	22,987	24,805	+1,818	+7.9%
Total, Nuclear Physics	350,589 [bc]	382,370	389,430	+7,060	+1.8%

[a] On December 20 2002, the National Nuclear Security Administration (NNSA) disestablished the Albuquerque, Oakland, and Nevada Operations Offices, renamed existing area offices as site offices, established a new Nevada Site Office, and established a single NNSA Service Center to be located in Albuquerque. Other aspects of the NNSA organizational changes will be phased in and consolidation of the Service Center in Albuquerque will be completed by September 30, 2004. For budget display purposes, DOE is displaying non-NNSA budgets by site in the traditional pre-NNSA organizational format.

[b] Excludes $7,777,000 that has been transferred to the SBIR program and $467,000 that has been transferred to the STTR program.

[c] Excludes $202,000 for the FY 2002 rescission contained in Section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to Terrorist attacks on the United States.

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 possible 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 Nuclear 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 ion-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 possible Rare Isotope Accelerator (RIA) facility. The combination of versatile beams and powerful instruments enables the ~230 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 uses 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 Van de Graaff, Booster Synchrotron, 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. 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 underway for the RHIC Spin program, with completion in FY 2004. 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 spectrometer arms that can track charged particles within a magnetic field especially to higher momentum; it provides excellent discrimination among photons, electrons, and hadrons. A Silicon Multiplicity Vertex Detector is used to locate the precise location of the collision point (different for each event), essential for measurement of the particle momenta with the spectrometer arms. 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 can be rotated to scan the broadest range of angles. It is especially designed to study the charged particle distributions in the forward and backward directions. Significant contributions (~$60,000,000) have been made by foreign institutions to these RHIC detectors and to implement the polarized proton capability.

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. 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 for medium energy physics experiments is terminating in FY 2003; however, the AGS will still be utilized to produce beams for tests of proton radiography for NNSA and for radiation damage studies to electronic systems for NASA supported work, among a variety of uses, with the support for these activities being provided by the relevant agencies.

The **Booster** Synchrotron, part of the RHIC injector, will provide heavy-ion beams to a dedicated beam line (Booster Application Facility, TPC~$33,900,000) for biological and electronic systems radiation studies funded by NASA as a Work-for-Others project to be completed in FY 2003. Upon completion operational costs will be supported by NASA.

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 (LE) subprogram, has been the operations and the research program of the 88-Inch Cyclotron, a national user facility. A major activity of this Low Energy group is the development of a next-generation gamma-ray detector system. 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 the KamLAND detector in Japan that are performing neutrino studies; (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. Operation of the 88-Inch Cyclotron as a Nuclear Physics user facility will be terminated in FY 2004.

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, in relativistic heavy ion experiments 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 162 acres in Newport News, Virginia. Constructed over the period FY 1987-1995 at a cost of $513,000,000, TJNAF began operations in FY 1995. Support for the research and operations of TJNAF are provided by the Medium Energy subprogram. The centerpiece 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 has a user community of ~1200 researchers and is used annually by ~700 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 of the strange quark contribution to nucleon structure, was completed during FY 2002. 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). The proposed upgrade to

CEBAF is one of the highest priority recommendations in the recently completed 2002 NSAC Long Range Plan for Nuclear Science.

All Other Sites

The Nuclear Physics program funds 181 research grants at 85 colleges/universities located in 35 states. Among these is a cooperative agreement 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 is the Bates Large Acceptance Spectrometer Toroid (BLAST) detector, whose fabrication was completed in FY 2001, underwent commissioning in FY 2002, and will begin its research program in FY 2003. BLAST will be used to observe collisions of polarized electrons in thin polarized gas targets located in the South Hall Pulse Stretcher Ring. The Bates experimental program is planned to terminate in 2005 with the completion of the BLAST program.

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. A new facility for producing intense photon beams using a free-electron laser (High Intensity Gamma Source) for studying photonuclear processes is just beginning its experimental program. ***The Texas A&M (TAMU) Cyclotron Institute*** operates a 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 the 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.

Medium Energy Nuclear Physics

Mission Supporting Goals and Measures

The Medium Energy Nuclear Physics subprogram supports fundamental research directed primarily at answering the first of the five broad questions listed in the 2002 Nuclear Science Advisory Committee Long Range Plan:

What is the structure of the nucleon? A quantitative understanding of the internal structure of the nucleons (protons and neutrons) requires a description of their observed properties in terms of the underlying quarks and gluons of Quantum Chromo-Dynamics (QCD), the theory of 'strong' interactions. Furthermore, this understanding would allow the nuclear binding force to be described in terms of the QCD interactions among the quarks.

To achieve the experimental description, the Medium Energy program supports different approaches that focus on:

(1) determining the distribution of (up, down, and strange) quarks in the nucleons,

(2) determining dynamic degrees of freedom of the quarks by measuring the excited states of hadrons (any composite particle made of quarks, such as nucleons),

(3) measuring the effects of the quark and gluon polarizations within the nucleon,

(4) determining the role of the "sea" of virtual quarks and gluons which also contributes to the properties of protons and neutrons, and

(5) measuring the properties of simple, few nucleon systems, with the aim to describe them in terms of the basic components.

Most of this work is done at this subprogram's primary research facility, Thomas Jefferson National Accelerator Facility (TJNAF), but the program also supports research at the MIT/Bates Linear Accelerator Center and the Relativistic Heavy Ion Collider at Brookhaven National Laboratory. Individual experiments are supported at the National Synchrotron Light Source at Brookhaven, the High Intensity Gamma Source at Triangle University Nuclear Laboratory, Fermilab, and at several facilities in Europe. All these facilities produce beams of sufficient energy (small enough wavelength) that they can probe at a scale within the size of a nucleon.

The operations of the two national user facilities, TJNAF and MIT/Bates, supported by 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. 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 European Center for Nuclear Research (CERN) member states. At TJNAF foreign collaborators have made significant investment in experimental equipment. Allocation of beam time at both Bates and TJNAF are based on guidance from Program Advisory Committees that review and evaluate proposed experiments regarding their merit and scientific priority.

The DOE Nuclear Physics program has made important discoveries in the past decade. 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. Advances in both theory and experiment have spurred this interest. The recent long-range plan singled out three significant achievements of the Medium Energy program related to the important central question of the structure of the nucleon:

- The combined discovery that the spins of the quarks alone account for only one third of the proton's overall spin and the observed increasing density of gluons inside the proton with increasing beam resolving power has increased the importance of the role of gluons in understanding nucleon structure.
- The discovery of a significant imbalance between antiquarks of different types inside the proton suggests that particles of quark-antiquark pairs called pions play as important a role inside the nucleon (via the virtual "sea" of quarks) as they do in theories of the nuclear force.
- The discovery in a new high-resolution spatial map of the proton points to an unexpected depletion of charge near its center, a fact not yet explained by current models.

These discoveries have been further extended by these recent highlights:

- *New precision results on the charge distribution of the neutron will test different models of the quark structure of the neutron:* Although a neutron has no net charge, it does have an internal distribution of charge due to the charged quarks inside. The precise determination of this charge distribution has been a major goal of nuclear physics for many years. Two dedicated experiments at TJNAF have obtained precise, high-resolution data on this distribution providing, for the first time, strong constraints for quark models of the neutron.
- *Data from disintegration of the deuteron by photons show a transition from quark to hadronic degrees of freedom:* New data from TJNAF on the breakup of the deuteron using gamma rays provide evidence that with increasing spatial resolution (power of magnification) one can see how the deuteron evolves from looking like a proton and a neutron bound together to an assembly of six quarks (the proton and neutron each containing three quarks). This result is important for scientists trying to understand when the individual quarks become important in describing the properties of the deuteron, the simplest compound nucleus.
- *Role of the strange quark in the proton's spin:* It had been thought that the strange quark should provide a negative contribution to the proton's internal "spin," or rotational angular momentum, of about 10%. Recent results from HERMES indicate that the contribution is consistent with zero or perhaps slightly positive. The near zero result rejects the hypothesis that the negative contribution of the strange quarks to the proton's spin could explain why the contribution of the 3 core quarks' spin does not add up to the proton's overall spin value.

Facility and Technical Accomplishments:

- *Fabrication of the BLAST Detector at the MIT/Bates facility is complete*: In FY 2002 the BLAST detector began commissioning activities; a unique research program will be initiated in FY 2003 to study the structure of the nucleon and few-body nuclei.
- *Fabrication of the G0 Detector is complete*: At the Thomas Jefferson National Accelerator Facility (TJNAF) the G0 Detector is complete and initiated commissioning at the end of FY 2002. 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 kinematic range.

- *The MiniBooNE detector fabrication is completed and operations begin:* Running of this jointly supported high-energy and nuclear physics experiment at Fermilab began in FY 2002 to look for the disapperance of muon neutrinos in an attempt to confirm the earlier result of the LSND experiment's observation of the disapperance of muon anti-neutrinos. With the observation of electron neutrino oscillations by the SNO experiment, this experiment becomes important for determining whether or not 'sterile' or non-interacting neutrinos exist.
- *The first Hydrogen-Deuterium frozen spin target is successfully demonstrated by the LEGS collaboration:* The LEGS collaboration at Brookhaven National Laboratory has demonstrated for the first time that an "ice" target made of hydrogen and deuterium can be polarized and operated in a beam of photons. This development is important for experiments on the structure of the proton and neutron for such "ice" targets have significantly cleaner experimental signatures than conventional polarized targets.

Subprogram Goal

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.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
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. [Mixed Results]	As elements of the electron beam program, (a) collect first data with the BLAST detector at MIT/Bates, studying the structure of nucleons and few body nuclei and (b) collect first data to map out the strange quark contribution to nucleon structure using the G0 detector, utilizing the high intensity polarized electron beam developed at TJNAF.	At MIT/Bates complete high-priority experiments with BLAST studying structure of nucleons and few body nuclei. At Thomas Jefferson National Accelerator Facility perform experiments, analyze data, and/or publish results by carrying out a peer-reviewed and prioritized research program directed towards determining the structure of nucleons, including: • the first experiment to study new theoretical functions that describe the proton structure (Generalized Parton Distributions), • measurements of the form factor of the pion and of the charge distribution of the ^{4}He nucleus, and • measurements to complete the first phase of the study of the excited states of the nucleon.

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
Commission polarized protons at RHIC. [Met Goal]	Collect first data with polarized protons with the RHIC STAR, PHENIX and pp2pp detectors.	At the Brookhaven Relativistic Heavy Ion Collider, perform experiments, analyze data, and/or publish results by carrying out a peer-reviewed research program studying the internal structure of the proton, including: • asymmetry measurements of pion production in collisions of polarized protons at high energy.

Funding Schedule

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Research					
University Research	15,670	15,575	15,432	-143	-0.9%
National Laboratory Research	14,554	16,815	15,708	-1,107	-6.6%
Other Research	315	5,405	5,405	0	0%
Subtotal, Research	30,539	37,795	36,545	-1,250	-3.3%
Operations					
TJNAF Operations	67,200	72,513	75,128	+2,615	+3.6%
Bates Operations	12,424	13,282	12,525	-757	-5.7%
Other Operations	1,055	0	0	0	0%
Subtotal, Operations	80,679	85,795	87,653	+1,858	+2.2%
Total, Medium Energy Nuclear Physics	111,218	123,590	124,198	+608	+0.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Research	**30,539**	**37,795**	**36,545**
▪ **University Research**	**15,670**	**15,575**	**15,432**

These activities comprise a broad program of research, and include support of about 165 scientists and 110 graduate students at 35 universities in 17 states and the District of Columbia. These research efforts utilize not only each of the accelerator facilities supported under the Medium Energy program, but also use other U.S. and 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 2002	FY 2003	FY 2004
	(dollars in thousands)		
▸ **Bates Research**	**2,130**	**2,835**	**2,500**

MIT scientists along with other university researchers are beginning a new program of research, starting in FY 2003, 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 and the South Hall Ring. Effort at Bates remains essentially constant.

▸ **Other University Research**	**13,540**	**12,740**	**12,932**

Most of the university research supports the activities associated with our main facilities at Bates, TJNAF and RHIC. At TJNAF the 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 neutron and the pion. The latter will provide new information to better understand the transition from the quark degrees of freedom to the hadronic degrees of freedom. Hall B will complete its initial experimental program on the excited states of the nucleon and focus on two new experiments, one to determine the half-life of the neutral pion and the other to explore a new technique called Deeply Virtual Compton Scattering (DVCS) for measuring quark structure functions called "Generalized Parton Distribution Functions". In Hall C, the G0 experiment, which will begin its experimental program in FY 2003, 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. Support is provided for data analysis from BLAST precision polarization measurements of the proton and nuclear structure measurements on light nuclei.

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.

In FY 2004 other university research funds are effectively increased by 2.3% compared to FY 2003 after correcting for shifts ($430,000) in grants in FY 2003 to the Theory and Low Energy subprograms. This will maintain an approximately constant effort for university research.

▪ **National Laboratory Research**	**14,554**	**16,815**	**15,708**

Included is: (1) the research supported at the Thomas Jefferson National Accelerator Facility (TJNAF), that houses the world's most powerful 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**.**

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		
▸ **TJNAF Research**	**5,770**	**5,945**	**5,405**

Scientists at TJNAF, with support of the user community, assembled the large and complex new experimental detectors for Halls A, B, and C. TJNAF scientists provide experimental support and operate the detectors 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. When a planned shift in FY 2003 of funds ($685,000) to the Theory Subprogram for enhanced theoretical effort at TJNAF is taken into account the FY 2004 funding provides a 2.8% increase from FY 2003.

As of FY 2002, Hall A will have completed 25 experiments and Hall C will have completed 17. The complex large-acceptance spectrometer in Hall B will have completed 65% of the data taking for 54 experiments. TJNAF researchers participate in all of these experiments.

TJNAF scientists are participating in the running of a new detector for the G0 experiment, in cooperation with the National Science Foundation. Beginning commissioning in FY 2002, the G0 detector will map out the contribution of the strange quark to the nucleon.

▸ **Other National Laboratory Research**	**8,784**	**10,870**	**10,303**

Support for research activities at accelerator and non-accelerator facilities at National Laboratories provides constant effort relative to FY 2003. These activities include:

- Argonne National Laboratory scientists will pursue research programs at TJNAF and at the DESY Laboratory in Germany. 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 new search for an electric dipole moment of the neutron.
- 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, the role of gluons. In FY 2003-2004, 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 completing a new spectrometer and a recently developed polarized "ice" target for a program of spin physics at low energies. This unique facility produces polarized gamma-rays by back scattering laser light from the circulating electron beam at the National Synchrotron Light Source (NSLS).

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		

– 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 Mini Booster Neutrino Experiment (MiniBooNE), uses neutrinos generated from the Fermi National Accelerator Laboratory Booster proton beam; data collection began 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 2002	FY 2003	FY 2004
▪ **Other Research**	**315**	**5,405**	**5,405**

In FY 2002 $4,219,000 was transferred to the SBIR program and $467,000 was transferred to the STTR program. This section includes $4,346,000 for SBIR and $510,000 for STTR in FY 2003 and $3,802,000 for SBIR and $1,048,000 for STTR in FY 2004 and other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

	FY 2002	FY 2003	FY 2004
Operations	**80,679**	**85,795**	**87,653**
▪ **TJNAF Operations**	**67,200**	**72,513**	**75,128**

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 2002	FY 2003	FY 2004
▸ **TJNAF Accelerator Operations**	**43,040**	**46,413**	**48,753**

Funding for accelerator operations in FY 2004 supports a 4000 hour running schedule. In FY 2002, the accelerator routinely delivered beams of differing energies and currents simultaneously to the three experimental halls. This funding level provides approximately constant effort in operations.

	(hours of operation with beam)		
	FY 2002	FY 2003	FY 2004
TJNAF	3960	4200	4000

Funding of $1,000,000 is provided for R&D activities that include $500,000 for the proposed upgrade of CEBAF to 12 GeV. This upgrade is recommended as one of the highest priorities for Nuclear Physics in the 2002 NSAC Long Range Plan for Nuclear Science. AIP funding includes polarized injector and beam handling components as well as other additions and modifications to the accelerator facilities. GPP funding is increased by $20,000 from FY 2003 providing for minor new construction and utility systems.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▸ **TJNAF Experimental Support**	**24,160**	**26,100**	**26,375**

Operating and equipment funding is provided for the experimental support needed to effectively carry out the TJNAF experimental program.

In FY 2004 support is maintained 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 and for cooling, radiation shielding, and special equipment for specific experiments. When a proposed shift in FY 2003 of funds ($315,000) for enhanced theoretical effort at TJNAF is taken into account, the FY 2004 funding level will provide a ~3% increase compared to FY 2003.

The G0 detector fabrication was completed in FY 2002. TJNAF is shifting their base capital equipment ($6,100,000) 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.

▪ **Bates Operations**	**12,424**	**13,282**	**12,525**

Funding for operations of the MIT/Bates Linear Accelerator Center are provided in FY 2004 to complete the BLAST scientific program. Termination of Bates is planned for FY 2005. During FY 2004 an evaluation will be made of the options for disposition of this facility and equipment, and of the associated Decommissioning and Decontamination cost and schedule.

	(hours of operation with beam)		
	FY 2002	FY 2003	FY 2004
Bates	5560	2700	4000

▪ **Other Operations**	**1,055**	**0**	**0**

Operation of the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory for a limited fixed-target program in medium energy physics was funded in FY 2002. No funds are provided for operation of the AGS in FY 2003 or FY 2004.

Total, Medium Energy Nuclear Physics	**111,218**	**123,590**	**124,198**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Research	
▪ **University Research**	
▸ Funding maintains the MIT/Bates research effort focused on effective collection and analysis of BLAST data. The level of effort remains essentially constant at Bates.	-335
▸ The research support at Other Universities is increased by 1.5% from FY 2003. As a result of transfer ($430,000) in FY 2003 of grant activities to Theory and Low Energy subprograms, this funding provides an approximately constant level of effort that is focused on the TJNAF and RHIC spin-physics research programs.	+192
Total, University Research	-143
▪ **National Laboratory Research**	
▸ Funding for capital equipment decreases by $691,000 from FY 2003 as projects are completed. Funding research support decreases by $416,000. The FY 2004 funding level for research support is effectively a ~2.6% increase from FY 2003 when the proposed shift of operating funds (~$835,000) to the Theory subprogram for enhanced theoretical effort in FY 2003 is taken into account.	-1,107
Total Research	-1,250
Operations	
▪ **TJNAF Operations**	
▸ **TJNAF Accelerator Operations:** Funding for accelerator operations is increased by $1,520,000 (3.4%) relative to FY 2003 in order to provide a 4000 hour running schedule. While the increase provides for somewhat less operating hours, actual scientific productivity is expected to increase due to higher beam reliability resulting from the increased funding. Funding for R&D is increased from FY 2003 by $500,000 (to $1,000,000, with $500,000 provided for the proposed 12 GeV upgrade) to maintain needed accelerator R&D manpower. AIP/GPP is increased by $320,000 compared to FY 2003 to maintain accelerator/physical infrastructure.	+2,340
▸ **TJNAF Experimental Support:** The increase of $275,000 for Experimental Support is effectively a ~3.0% increase relative to FY 2003 (after accounting for the proposed shift in FY 2003 of $315,000 to the Theory subprogram) in order to provide an approximately constant effort for supporting the experimental program. Overall capital equipment funding ($6,100,000) remains the same as FY 2003.	+275
Total, TJNAF Operations	+2,615

	FY 2004 vs. FY 2003 ($000)
▪ **Bates Operations**	
▸ The funding for Bates operations is decreased from FY 2003 since FY 2004 will be the last year of running to complete the BLAST program. Operating funds are increased (+$818,000) and capital equipment and accelerator improvement projects (AIP) funds are decreased (-$1,575,000).	-757
Total Operations	+1,858
Total Funding Change, Medium Energy Nuclear Physics	+608

Heavy Ion Nuclear Physics

Mission Supporting Goals and Measures

The Heavy Ion Nuclear Physics subprogram supports research directed at answering one of the central questions of nuclear science identified in the Nuclear Science Advisory Committee (NSAC) 2002 Long Range Plan:

(1) *What are the properties of hot nuclear matter?* At normal temperatures and densities, nuclear matter contains individual protons and neutrons (nucleons), within which the quarks and gluons are confined. At extremely high temperatures, however, such as those that existed in the early universe immediately after the "Big Bang," the quarks and gluons become deconfined and form a quark-gluon plasma. It is the purpose of this research program to recreate this phase of matter in the laboratory by colliding heavy nuclei at relativistic energies. The distributions and properties of particles emerging from these collisions are studied for the predicted signatures of the quark-gluon plasma to establish its existence and further characterize its properties experimentally. At much lower temperatures, nuclear matter passes through another phase transition from a Fermi liquid to a Fermi gas of free roaming nucleons; understanding this phase transition is also a goal of this program.

Historically, 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 (RHIC) at Brookhaven National Laboratory. First gold-gold collisions were observed at RHIC in 2000. The Heavy Ion research program, now almost exclusively performed at RHIC, 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." Limited studies of the conditions for inducing the liquid-to-gas phase transitions in nuclear matter are also going on at the National Superconducting Cyclotron Laboratory (NSF funded) at Michigan State University, at Texas A&M University, and at foreign laboratories.

The Heavy Ion Nuclear Physics subprogram supports operation of the RHIC facility at Brookhaven National Laboratory. 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. Two successful running periods have been completed, Run 1 in FY 2000 and Run 2 which spanned the end of FY 2001 and the beginning of FY 2002. The RHIC facility is utilized by over 1,100 DOE, NSF, and foreign supported researchers. capital equipment and accelerator improvement project (AIP) funds are provided for additions, modifications, and improvements to the various accelerators that make up the RHIC complex and to the ancillary experimental facilities, in order to maintain and improve the reliability and efficiency of operations, and to provide new experimental capabilities. The allocation of beam time at RHIC is made with the guidance of a Program Advisory Committee, consisting of distinguished scientists, that reviews and evaluates proposed experiments regarding their merit and scientific priority. An annual peer review of the effectiveness of RHIC operations and its research program is conducted by the program office; the recommendations from these reviews are used to improve RHIC operations.

The recent NSAC long-range plan identified several recent discoveries that support the goals of the Heavy Ion Program:

- Production of small regions of space with energy densities more than twenty times that of atomic nuclei. Matter under these extreme conditions is believed to be in the quark-gluon plasma phase.
- Observation of a strong "flow" of matter in relativistic heavy-ion collisions, that indicates that the initial kinetic energy of the beams is rapidly converted to heating the nuclear matter created in the collision zone, putting it under immense internal pressure.
- Observation of a deficit of high transverse-energy particles in relation to proton-proton collisions. This result indicates that high-energy particles suffer energy losses much larger than those expected for the partons (making up the particles) passing through normal nuclear matter – hinting at the formation of the plasma phase in the collision.
- Measurements of anti-matter to matter ratio. Since the number of anti-baryons (anti-matter) is almost equal to the number of baryons (matter), it is concluded that the collision zone immediately after the collision consists of almost only pure energy, out of which the particles are produced.

These discoveries have been further extended by these recent highlights:

- *First lepton measurements – open charm:* First measurements of high-energy electrons at RHIC show that their yields are consistent with the electrons originating from decays of D-mesons, which contain a single heavy charm quark. The study of charmed quark production and the survival probability of J/ψ-mesons (consisting of a pair of charm and anti-charm quarks) in the hot collision zone is expected to be a critical signal for demonstrating that the quark-gluon plasma has been formed.
- *Observation of the liquid-gas phase transition in nuclear matter* – At low temperatures nuclear matter behaves like a quantum mechanical (Fermi) liquid, but it is expected that it will go through a phase transition (start to boil) when heated to sufficiently high temperatures and assume the characteristics of a (Fermi) gas. Recently, this long-predicted phase transition has been observed in experiments where gold nuclei are heated by absorbing anti-protons or pions from the AGS into gold nuclei. The results show that this phase transition occurs in nuclear matter at a temperature of 4-6 MeV.

Facility and Technical Accomplishments:

- *The Relativistic Heavy Ion Collider (RHIC) reaches full luminosity:* At Brookhaven National Laboratory commissioning of RHIC 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) and beam energies of 65 GeV per nucleon, as planned. RHIC operated at full beam energies of 100 GeV per nucleon for gold-gold collisions in late FY 2001 and in early FY 2002 full luminosity (collision rate) was achieved. Both running periods supported very successful physics research programs.
- *RHIC obtains first collisions of polarized protons from two colliding beams:* The RHIC Spin program at Brookhaven National Laboratory successfully accelerated polarized protons in the two RHIC rings with about 25% polarization at energies of 100 GeV in early CY 2002. The polarization

was between 80-100% of injection polarization. This demonstrated that polarized protons can be successfully accelerated in the rings and set a new record for the highest energy polarized proton beam ever achieved as well as the first collisions of polarized protons.

- *RHIC detector enhancements remain on cost and schedule:* In FY 2002, a Critical Decision-4 (CD-4, Start of Operations) was approved for the STAR Silicon Vertex Detector (SVT), a high resolution, high granularity, charged-particle tracking system very close to the collision region. A CD-4 was also obtained for the first PHENIX muon arm (MIE); the second arm (funded substantially by the Japanese collaborators) was completed in FY 2002. The Electromagnetic Calorimeter (EMCAL) of STAR is on schedule for completion of the planned system in FY 2003.

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 that are needed for effective laboratory operations.

Subprogram Goal

Determine the behavior and properties of hot, dense nuclear matter as a function of temperature and density; establish whether a quark-gluon plasma can be created in the laboratory and, if so, characterize its properties.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
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. [Met Goal]	Initiate first round of experiments with collisions with other ions to compare to results of gold-gold collisions.	At the Relativistic Heavy Ion Collider, perform experiments, analyze data, and/or publish results by carrying out a peer-reviewed and prioritized research program directed towards determining the behavior and properties of hot, dense nuclear matter, including: • Measurements of the thermodynamic and hydrodynamic properties of hot nuclear matter; and • Measurements of the yields of high transverse momentum particles through hot and cold nuclear matter.

Funding Schedule

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Research					
University Research	11,530	11,635	12,083	+448	+3.9%
National Laboratory Research	18,903	21,194	18,873	-2,321	-11.0%
Other Research	0	3,291	3,902	+611	+18.6%
Subtotal, Research	30,433	36,120	34,858	-1,262	-3.5%
Operations					
RHIC Operations	103,344	117,497	121,057	+3,560	+3.0%
Other Operations	17,496	14,360	11,890	-2,470	-17.2%
Subtotal, Operations	120,840	131,857	132,947	+1,090	+0.8%
Total, Heavy Ion Nuclear Physics	151,273	167,977	167,805	-172	-0.1%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Research	**30,433**	**36,120**	**34,858**
▪ **University Research**	**11,530**	**11,635**	**12,083**

Support is provided for the research of about 130 scientists and 75 graduate students at 26 universities in 18 states. *There is a $448,000 increase compared to FY 2003 that provides a 3.9% increase in grant funding.*

- Researchers using relativistic heavy ion beams are 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.
- Researchers using primarily the NSF supported National Superconducting Cyclotron Laboratory at Michigan State University, at the DOE supported 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.

▪ **National Laboratory Research**	**18,903**	**21,194**	**18,873**

Support is provided for scientists from five National Laboratories (BNL, LBNL, LANL, LLNL and ORNL). These scientists provide essential manpower for the operations of the RHIC detectors and in analyzing data. 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.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▸ **BNL RHIC Research**	**9,177**	**9,153**	**8,696**

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 contribute to the search for signatures of any new forms of nuclear matter produced in heavy-ion collisions. *In FY 2004 funding for capital equipment decreases by $703,000 to $2,300,000, with the completion of projects, while support for manpower increases 4.0%.* Funding for production of modules for the Electromagnetic Calorimeter Enhancement for the STAR RHIC-spin program is beginning in FY 2003; the enhancement will be completed in FY 2004. The survey work with gold ions at the full energy will be substantially complete by FY 2004 and measurements of the yields of rarer signals, such as J/ψ suppression due to its breakup by the quark-gluon plasma, will dominate the experimental program. Two new major detector subsystems will be ready for these investigations in FY 2004:

– The muon instrumentation for PHENIX allows measurement of the yields of muons ("heavy electrons") that (1) probe the early stages of quark-gluon plasma formation in heavy-ion collisions, and (2) perform critical measurements in the PHENIX RHIC Spin program. Completed in FY 2002, this system will be used for the FY 2003 Run-3 running period. Japanese and French collaborators are contributing substantial support for the muon arms.

– The Electromagnetic Calorimeter for STAR provides capability to distinguish electrons from photons, and extends the measurement to higher particle 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 and be completed in FY 2004.

▸ **Other National Laboratory Research**	**9,726**	**12,041**	**10,177**

Researchers at LANL, LBNL, LLNL, and ORNL provide leadership in the commissioning of the PHENIX muon arms 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 decrease in funding of $2,065,000 to $275,000 for capital equipment compared to FY 2003 reflects the completion of projects; support for manpower increases by 2.1% for about constant effort.

▪ **Other Research**...	**0**	**3,291**	**3,902**

In FY 2002 $2,903,000 was transferred to the SBIR program. This section includes $3,291,000 for SBIR in FY 2003 and $3,902,000 for SBIR in FY 2004.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Operations	**120,840**	**131,857**	**132,947**
▪ **RHIC Operations**	**103,344**	**117,497**	**121,057**

The Relativistic Heavy Ion Collider (RHIC) program nearly reached its full planned capabilities by the end of the planned running period Run 2 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 described theoretically. Already during the first runs in FY 2000 (Run 1) and FY 2001/FY 2002 (Run 2), new features were observed in the data indicating that conditions are favorable for quark-gluon plasma formation and hints of some characteristic signatures of its existence. The scientific papers that have been published from these results have generated much attention in the community. During the Run 2, operation with 100 GeV polarized protons was accomplished and some initial measurements for the spin-physics program were completed.

► **RHIC Accelerator Operations**	**75,823**	**86,950**	**90,232**

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. Operations in FY 2003 are expected to increase to 22 weeks (3300 hours) from the 18-week operating schedule (2110 hours) in FY 2002. *FY 2004 funding will support a 29-week schedule (3480 hours) for research, about a 5% increase in hours from FY 2003. After accounting for an anticipated shift of $400,000 to the Theory subprogram in FY 2003 for enhanced theoretical effort, in response to the NSAC Long Range Plan recommendation, there is a 4.3% increase in FY 2004 for operations. Capital equipment funding is increased from FY 2003 by $100,000 to $1,100,000* and AIP funding of $2,900,000 is maintained at the same level as FY 2003, providing for needed improvements especially to legacy systems such as the AGS main magnet power supply as well as for design efforts for the Electron Beam Ion Source (EBIS).

RHIC Operations

	(hours of operation with beam)		
	FY 2002	FY 2003	FY 2004
RHIC	2110	3300	3480

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▸ **RHIC Experimental Support**......................................	**27,521**	**30,547**	**30,825**

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) nearly reached their initial planned potential by FY 2002. About 1,100 scientists and students from 82 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. After accounting for a proposed shift of $200,000 in FY 2003 to the Theory subprogram there is a 1% increase in support in FY 2004. Capital equipment is increased by $228,000 from FY 2003.

	FY 2002	FY 2003	FY 2004
▪ **Other Operations**	**17,496**	**14,360**	**11,890**

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 2004 funding for GPP and GPE is decreased by $50,000 (-0.3%) relative to FY 2003, by reducing usage of motor vehicles.

	FY 2002	FY 2003	FY 2004
Total, Heavy Ion Nuclear Physics..	**151,273**	**167,977**	**167,805**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Research	
▪ **University Research**	
▸ FY 2004 funding for grants for University Research increases by 3.9%, maintaining an approximately constant effort relative to FY 2003 focused on carrying out an effective and productive research program at RHIC..	+448
▪ **National Laboratory Research**	
▸ **BNL RHIC Research:** Research support is increased by $246,000 (+4.0%) to effectively carry out research with the enhanced detectors at full luminosity at RHIC. Funding for capital equipment is decreased by $703,000 because of completion of projects...	- 457

	FY 2004 vs. FY 2003 ($000)
▸ **Other National Laboratory Research:** Research support for operations is increased by $201,000 (+2.1%) compared to FY 2003, maintaining approximately constant manpower. Funding for capital equipment decreases by $2,065,000 compared with FY 2003, with the completion of projects.	-1,864
Total, National Laboratory Research	-2,321
▪ **Other Research:**	
▸ Estimated SBIR and other obligations increase.	+611
Total, Research	-1,262
Operations	
▪ **RHIC Operations**	
▸ **Accelerator Operations:** An increase of $3,182,000 (+3.8%) in operating funds provides an enhancement of effort resulting in ~3,480 hours of beam for research, about 5% greater than in FY 2003. Funding of capital equipment is increased $100,000 relative to FY 2003 to maintain accelerator capabilities.	+3,282
▸ **Experimental Support:** The increase provides a funding level for experimental support that is needed to carry out the RHIC experimental program.	+278
Total, RHIC Operations	+3,560
▪ **Other Operations**	
▸ FY 2004 funding for general plant projects to Brookhaven National Laboratory is increased by $60,000 (+1%) compared with FY 2003. Funding for general purpose equipment is decreased by $110,000 (-2.4%). Other operations decrease by $2,420,000.	-2,470
Total, Operations	+1,090
Total Funding Change, Heavy Ion Nuclear Physics	-172

Low Energy Nuclear Physics

Mission Supporting Goals and Measures

The Low Energy Nuclear Physics subprogram supports research directed at understanding three of the central questions of nuclear science identified in the NSAC 2002 Long Range Plan:

(1) *What is the structure of nucleonic matter?* 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.

(2) *What is the nuclear microphysics of the universe?* 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.

(3) *Is there new physics beyond the Standard Model*? Studies of fundamental interactions and symmetries, including those of neutrino oscillations, are indicating that our current Standard Model is incomplete, opening up possibilities for new discoveries by precision experiments.

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 2002 NSAC Long Range Plan identified RIA as the highest Nuclear Physics priority for a major new construction project. Starting in FY 2000, R&D activities have been supported in preparation for a possible request for approval for construction. Continued funding for these pre-conceptual R&D activities is supported in FY 2004.

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. In FY 2004 the Low Energy Nuclear Physics subprogram supports the operation of two national user facilities: the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory and the Argonne Tandem Linac Accelerator System (ATLAS) facility at Argonne National Laboratory. Operations at the 88-Inch Cyclotron (LBNL) are terminated as a nuclear physics user facility in order to provide resources to optimize the utilization and science productivity of the remaining user facilities. These facilities are utilized by DOE-, NSF-, and foreign-supported researchers. The allocation of beamtime is made with the guidance of Program Advisory Committees, consisting of distinguished scientists, who review and evaluate proposed experiments regarding their merit and scientific priority. 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. These students historically have become 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 Sudbury Neutrino Observatory (SNO) detector is studying the production rate and properties of solar neutrinos, while the Kamioka Large Anti-Neutrino Detector (KamLAND) is studying the properties of anti-neutrinos produced by nuclear power reactors.

Research in the Low Energy subprogram continues to evolve to address forefront scientific questions. The 1990's began with research efforts at the 88-Inch 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, conceived in the late 1980's to search for neutrino flavor oscillations due to their having mass, was designed and built in the 1990's. In 2001, SNO reported its first physics results, which together with other experimental results, made a persuasive case for neutrino oscillations among their different types (or "flavors") and that neutrinos have mass. These results have been confirmed by new measurements reported in 2002 from SNO that are sensitive to the different types of neutrinos, and from the first KamLAND results with reactor produced anti-neutrinos. Both of these experiments have shown that neutrinos "oscillate" or change flavor as they propagate from the source to detector – this property requires that they have mass. These results have stimulated an increasing interest in non-accelerator experiments, particularly those that study neutrino properties. A priority in the FY 2004 request is increased support for this research area.

The 2002 Long Range Plan identified significant achievements of the Low Energy subprogram that are related to the important central questions about nuclear structure, nuclear astrophysics, and fundamental interactions and symmetries:

- Studies of nuclei at extreme conditions are pointing to alterations of the nuclear shell structure, the ability of heavy nuclei to sustain rapid rotation demonstrating unexpected stability, and evidence for phase transitional behavior between spherical and deformed nuclei.
- Nuclear measurements of very neutron-rich, unstable nuclei, combined with new computational techniques, are leading to a better identification of the *r*-process site or sites for nucleosynthesis and to quantitative models for the production of heavy elements.

- Measurements of solar neutrinos have indicated that neutrinos change their identity on the way to earth, implying that they have mass, and providing a key to the fundamental structure of the forces of nature.

The basic knowledge and understanding in these areas have been further extended by these recent highlights:

- *Identification of hyper-intruder states*: Scientists at LBNL have identified the gamma-ray decay of nuclear states based on very extended shapes in ^{108}Cd. These structures may correspond to the most deformed nuclei observed to date. Microscopic calculations suggest that the proton orbitals that are the basis of the new structures in ^{108}Cd are the same as those involved in superdeformed structures of the much heavier mass 150 nuclei and the ground states of much heavier uranium nuclei. These newly discovered "hyper-intruder" states are thought to be a key ingredient for stabilizing football-like shapes with a 3:1 axis ratio in some nuclei.
- *First studies with re-accelerated neutron-rich radioactive ion beams*: Beams of re-accelerated radioactive tin and tellurium have been used at ORNL's Holifield Radioactive Ion Beam Facility to perform Coulomb excitation and transfer reaction studies of nuclear structure in the vicinity of ^{132}Sn, a nucleus with closed shells of both protons and neutrons. The initial Coulomb excitation results suggest that present theoretical models may not be able to adequately describe the low-lying structure of ^{136}Te, a nucleus with just two neutrons beyond the closed N = 82 shell.
- *First neutral current results from SNO:* Researchers at the Sudbury Neutrino Observatory reported the first neutral current measurements of neutrinos from the sun, a measurement made possible by the SNO detector's heavy water medium. The neutral current results show for the first time that the measured solar neutrino flux agrees with theoretical estimates. These results, together with the charged current results (sensitive to only the electron neutrino) SNO reported last year, provide evidence that the electron neutrinos originating in the sun change to one or both of the other neutrino types (muon and tau) by the time they are detected on earth, and indicate that neutrinos have a mass.

Facility and Technical Accomplishments:

- *Performance of the gas cell fast ion catcher:* The gas cell fast ion catcher is an essential component of the Rare Isotope Accelerator that will allow that facility to combine the best features of the fragmentation and isotope-separator-on-line techniques for production of exotic nuclei. At ANL a quarter-scale version of the gas cell has provided an efficiency of about 45% for stopping, collecting, and delivering charge 1+ radioactive ions for further study. A mean delay time of 10 milliseconds has been demonstrated for this device. A full-scale version of the gas cell fast ion catcher has been fabricated for high power tests to be conducted at the GSI accelerator facility in Germany.
- *Kamioka Large Anti-Neutrino Detector (KamLAND) begins operations*: The construction of this joint Japanese/U.S. detector project was completed and began operation in FY 2002. This experiment will detect anti-neutrinos from Japanese nuclear power plants and will provide complementary information regarding neutrino properties to the recent Sudbury Neutrino Observatory (SNO) results. U.S. participation in KamLAND is supported jointly with the High Energy Physics program
- *Development of segmented Germanium detectors:* Preconceptual design of a detector cluster module consisting of three Ge crystals in a cryostat was completed. The crystals are divided into 36 electrically isolated segments. This represents the final step in developing the technology for a 4π array that will be up to 1000 times more sensitive than Gammasphere, presently the most powerful gamma-ray detector in the world.

Subprogram Goal

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.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
		Perform experiments, analyze data, and/or publish results by carrying out a peer-reviewed and prioritized research program, including: • at the Argonne Tandem Linac Accelerator System (ATLAS) measure masses with high precision of nuclear astrophysically important radioactive nuclei, identify collective excitations in actinide nuclei, and develop new exotic beams for nuclear astrophysics and structure studies; • at the Holifield Radioactive Ion Beam Facility (HRIBF), use stable and radioactive ion beams (RIBs) to measure the properties of reactions that are important for understanding the synthesis of elements in stellar explosions and necessary for interpretation of solar neutrino experiments, and measure shapes of neutron-rich nuclei.
Collect the first data from neutral current interactions from the Sudbury Neutrino Observatory (SNO). [Met Goal]	Collect the first data from the Kamioka Large Anti-Neutrino Detector (KamLAND), a joint U.S.-Japan experiment measuring neutrinos produced in nuclear reactors.	With KamLAND, perform experiments, analyze data, and publish results, completing the first measurement of reactor-produced neutrinos with this detector.
Construct a prototype high energy, high power gas catcher for the possible Rare Isotope Accelerator. [Met Goal]	Deliver the prototype high energy, high power gas catcher to the GSI facility in Germany and prepare it for testing. Complete tests of prototype targets for RIA. Complete prototype Electron Cyclotron Resonance ion source and fabricate prototypes of the high-beta superconducting radio frequency (RF) cavities for RIA.	As part of R&D for the possible RIA, complete test of the high-beta superconducting RF cavities.

Funding Schedule

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Research					
University Research	17,123	17,591	18,312	+721	+4.1%
National Laboratory Research	20,109	20,044	23,244	+3,200	+16.0%
Other Research	3,150	4,743	4,903	+160	+3.4%
Subtotal Research	40,382	42,378	46,459	+4,081	+9.6%
Operations	22,387	23,780	22,830	-950	-4.0%
Total, Low Energy Nuclear Physics	62,769	66,158	69,289	+3,131	+4.7%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Research	**40,382**	**42,378**	**46,459**
▪ **University Research**	**17,123**	**17,591**	**18,312**

Support is provided for the research of about 140 scientists and 90 graduate students at 32 universities in 23 states. Nuclear Physics university scientists perform research as users 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, the production mechanisms of the chemical elements in stars and supernovae, and the properties of neutrinos. FY 2004 funding for operation of university accelerator facilities, and for researchers and students is increased by 6.8% compared to FY 2003, with priority given to non-accelerator research. Funding for capital equipment projects is decreased by $353,000. Research activities include:

- 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 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 that 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.

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

- 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 2002	FY 2003	FY 2004
▪ **National Laboratory Research**	**20,109**	**20,044**	**23,244**

Support is provided for the research programs of scientists at six National Laboratories (ANL, BNL, LBNL, LANL, LLNL and ORNL).

	FY 2002	FY 2003	FY 2004
▸ **National Laboratory User Facility Research**............	**14,123**	**14,455**	**14,345**

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 2004 funding is increased ~0.6% for manpower while investments in equipment decrease by $200,000 from FY 2003. In FY 2004 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 being utilized in an experimental program in nuclear astrophysics.
- At ANL the research focuses on the use of stable and selected radioactive beams from ATLAS, coupled to ion traps, Gammasphere and the Fragment Mass Analyzer to study fundamental processes and properties of nuclei, and to study nuclei at the extremes of excitation energy, angular momentum, deformation and 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 tested and the experimental program initiated.
- At LBNL the research focuses on the completion of data analysis from the terminated research program at the 88-Inch Cyclotron and the use of DOE user facilities to study nuclei at high angular momentum and deformation. Development and 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.

	FY 2002	FY 2003	FY 2004
▸ **Other National Laboratory Research**	**5,986**	**5,589**	**8,899**

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. *FY 2004 funding for manpower increases by ~2.6% from FY 2003 with priority given to non-accelerator research. Capital equipment investments increase from FY 2003 by $3,176,000 to $3,641,000.* These activities include:

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

- 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 and 2002, the first results from SNO with the heavy water detector were reported, indicating strong evidence for neutrino oscillations. Results from the second phase measurements of neutrino types to which the solar neutrinos have been transformed will be reported in FY 2003. In FY 2003, the third phase of SNO began; it will provide additional detail and confirmatory information on neutrino oscillations. Results from this phase are expected to be reported in FY 2004-2005.
- The KamLAND experiment in Japan will measure the rate and properties of anti-neutrinos produced by several distant nuclear power reactors to study neutrino "oscillations." KamLAND has the advantage of comparing the measured fluxes to known sources. Commissioning of the KamLAND detector began in FY 2002, with data collection continuing in FY 2003 and FY 2004. The U.S. participation in KamLAND is supported jointly with the High Energy Physics program.
- 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. Commissioning of neutron experiments with these beams will begin in FY 2004. Funds ($500,000) are provided in FY 2004 to begin development of a beamline for neutron studies at the Spallation Neutron Source (SNS) (an MIE).
- Development and fabrication of a segmented germanium gamma-detector array, the Gamma-Ray Energy-Tracking In-beam Nuclear Array (GRETINA) begins, that is especially useful for the study of the nuclear decay and structure of exotic nuclei in fast fragmentation beams, and a smaller version of the proposed GRETA detector for the Rare Isotope Accelerator. The improved position resolution and higher efficiency for high-energy gamma rays compared with presently available gamma-ray detector arrays will allow this new detector system to utilize fragmented nuclear beams to open up a new frontier for understanding exotic nuclei that may exist in stars and supernovae, but live only briefly (fractions of a second). In FY 2004 funding of $1,000,000 is provided to begin fabrication of GRETINA (a Major Item of Equipment).

	FY 2002	FY 2003	FY 2004
▪ **Other Research**	**3,150**	**4,743**	**4,903**
▸ **RIA R&D Activities**	**2,800**	**3,500**	**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 2002 Nuclear Science Advisory Committee (NSAC) Long Range Plan as a compelling scientific opportunity and as the highest priority for new construction. The possible RIA facility is a new paradigm for producing intense beams of very short-lived nuclei that emerged from the 1999 NSAC Taskforce study involving international experts. This facility would position the

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

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 phenomena. Funding for FY 2004 supports some of the needed R&D activities in both critical accelerator components and experimental station development.

	FY 2002	FY 2003	FY 2004
► **SBIR and Other**	**350**	**1,243**	**1,403**

In FY 2002 $655,000 was transferred to the SBIR program. This section includes $868,000 for SBIR in FY 2003 and $1,028,000 for SBIR in FY 2004 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.

	FY 2002	FY 2003	FY 2004
Operations	**22,387**	**23,780**	**22,830**
▪ **User Facility Operations**	**22,387**	**23,780**	**22,680**

Support is provided for the operation of two National User Facilities, the Argonne Tandem-Linac Accelerator System (ATLAS) at ANL 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. Accelerator improvement project funding is increased from FY 2003 by $1,000,000 in order to fabricate a platform for development and testing targets and ion sources.

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.

Operations at the 88-Inch Cyclotron as a Nuclear Physics user facility are terminated in FY 2004 to provide resources to optimize the utilization and science productivity of the remaining user facilities and to be consistent with the recommendations of the NSAC Low Energy Program Review in 2001. In FY 2003 options for this facility will be evaluated and the estimated cost and schedule for the appropriate Decommissioning and Decontamination (D&D) activities will be developed. Funds of $3,000,000 are provided in FY 2004 for these phaseout activities. While the final D&D cost and schedule have not been established, it can be anticipated that these activities will continue for 2-4 years.

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.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

In FY 2004 these low energy facilities will carry out about 95 experiments involving over 360 U.S. and foreign researchers. Planned hours of operation with beam are indicated below:

	(hours of operation with beam)		
	FY 2002	FY 2003	FY 2004
ATLAS	5,485	4,050	6,500
HRIBF	4,250	2,600	3,780
88-Inch Cyclotron	4,480	3,850	0
Total Beam Hours for Low Energy Facilities	14,215	10,500	10,280

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▪ **Other Operations**	**0**	**0**	**150**
Funding is provided for maintenance of the Oak Ridge Electron Accelerator (ORELA) for criticality measurements supported by DOE/NNSA........................	0	0	150
Total, Low Energy Nuclear Physics..	**62,769**	**66,158**	**69,289**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Research	
▪ **University Research**	
▸ FY 2004 funding for researchers and students is increased by 6.8% ($1,074,000) from FY 2003. Priority will be given to supporting non-accelerator research activities such as SNO and KamLAND. Additional support is provided for operating university accelerator facilities and utilizing national user facilities. Funding for capital equipment decreases by $353,000 compared to FY 2003 as projects are completed.	+721
▪ **National Laboratory Research**	
▸ **National User Facilities Research:** FY 2004 funding provides about constant funding of +0.6% ($90,000) for research efforts and activities at the user facilities while capital equipment funds are reduced by $200,000. Because of the proposed transfer in FY 2003 of $380,000 to the Theory subprogram from this funding category, the effective increase for research efforts is $450,000 (+3.4%)................	-110

	FY 2004 vs. FY 2003 ($000)
▸ **Other National Laboratory Research**: Research funding increases about 2.6% ($134,000) in FY 2004 compared with FY 2003. Manpower and effort will be focused on the high priority non-accelerator research activities including SNO and KamLAND. Equipment funds are increased by $3,176,000 to address scientific opportunities identified in the NSAC 2002 Long Range Plan for Nuclear Science, such as the Fundamental Neutron Physics Beamline at the Spallation Neutron Source and the GRETINA gamma-ray tracking detector.	+3,310
Total, National Laboratory Research	+3,200
▪ **Other Research**	
▸ **SBIR and Other:** Estimated SBIR and other obligations increase.	+160
Total, Other Research........	+160
Total Research........	+4,081
Operations	
▪ In FY 2004 operating funds are increased by ~6.1% ($900,000) compared to FY 2003 for ATLAS and HRIBF operations to provide an estimated 10,280 hours of beam time. Funding for capital equipment and accelerator improvement projects at these facilities increases by $1,300,000 compared to FY 2003. Operations of the 88-Inch Cyclotron at LBNL is terminated with a reduction of $3,300,000 in operations and equipment costs........	-1,100
▪ Other operations are increased by $150,000 to provide maintenance of the Oak Ridge Electron Accelerator (ORELA) for criticality measurements supported by DOE/NNSA.	+150
Total Operations	-950
Total Funding Change, Low Energy Nuclear Physics	+3,131

Nuclear Theory

Mission Supporting Goals and Measures

Progress in nuclear physics, as in any science, depends critically on improvements in the theoretical techniques and on new insights that will lead to new models and theories that can be applied to interpret experimental data and predict new behavior. The Nuclear Theory subprogram supports research directed at understanding the five central questions identified in the NSAC 2002 Long Range Plan:

(1) *What is the structure of the nucleon?* Protons and neutrons are the basic components of all observable matter in the universe that are themselves made-up of lightweight, point-like particles, called quarks and gluons. The fundamental theory governing the dynamics of quarks and gluons is known as Quantum Chromodynamics (QCD). A key goal of modern theoretical nuclear physics is to comprehend the intricate structure and properties of the nucleon and ultimately nuclei, in terms of the interactions between the quarks, gluons and the extraordinarily complex vacuum.

(2) *What is the structure of nucleonic matter?* Nuclear theorists strive to understand the diverse structure and remarkable properties of the nucleus. With the possibility of obtaining new experimental results for unstable nuclei from studies with radioactive beams, theorists will be able to probe nuclei at limits of high excitation energy, deformation, and isotopic stability. Ultimately, this major frontier of research will permit the development a "comprehensive model" for nuclei that is applicable across the entire periodic table.

(3) *What are the properties of hot nuclear matter?* The properties of hot, dense nuclear matter, is the central topic of research at the new Relativistic Heavy Ion Collider (RHIC) facility. Lattice QCD theory predicts that the physical vacuum "melts" at extremely high temperatures and the underlying symmetries of QCD restored. Under these conditions, normal nuclear matter should transform into a plasma of nearly massless quarks and gluons – a new form of matter that is believed to have pervaded the primordial universe a few microseconds after the Big Bang. Theoretical research provides the framework for interpreting the experimental measurements for evidence of the quark-gluon plasma and other new phenomena. A key goal of the theoretical program is to establish knowledge of the QCD phase diagram of bulk nuclear matter.

(4) *What is the microphysics of the universe?* The theory subprogram attempts to understand the nuclear microphysics of the universe that involve fundamental nuclear physics processes, such as the origin of elements; the structure and cooling of neutron stars; the properties of neutrinos from the sun and the mechanism of core-collapse supernovae.

(5) *Is there new physics beyond the Standard Model?* The search for a single framework describing all known forces of nature – the so-called 'Standard Model' represents a formidable challenge. The current version of the Standard Model has been tested with impressive precision in experiments with atoms, in various nuclear experiments testing Standard Model symmetries, and in high-energy experiments. However, despite its successes, recent experimental observations of neutrino behavior and studies of fundamental symmetries present some conceptual difficulties that lead physicists to believe a more fundamental theory must exist.

The research of this program is conducted entirely by groups and individual researchers located at universities and DOE national laboratories. The researchers utilize the high performance computational facility at the National Energy Research Scientific Computing Center (NERSC) at the Lawrence Berkeley National Laboratory and other specialized computers at other institutions. This subprogram sponsors the national Institute for Nuclear Theory (INT), based at the University of Washington, in Seattle, Washington, where visiting scientists focus on key frontier areas in nuclear physics, including those crucial to the success of existing and future experimental facilities and the education of postdoctoral researchers and graduate students.

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 the RIKEN Center 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 the theory 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. Progress in Nuclear Theory is reviewed as a component in reviews of the three other major program components of the Nuclear Physics program.

The 2002 Long Range Plan highlights many significant theoretical advances in all of the five major frontiers of research in nuclear physics today. A few of the most recent accomplishments are:

- *Structural phase transitions in nuclei:* Nuclei are known to exhibit exotic shapes, but describing the detailed properties of nuclei in the phase-transition region has been a long standing challenge. An analytical model, called the X(5) symmetry, has been developed to predict the properties of various spherical nuclei that transform into a rugby-ball shape during a phase transition. This theory could also be applied to metallic clusters, molecules and polymers. Recently, experimenters have found ^{152}Sm co-exists as a spherical and rugby-ball nucleus; an observation that is in agreement with the X(5) symmetry model. This exciting confirmation could lead to a new direction in nuclear physics research when more exotic nuclei becoming readily available at radioactive beam facilities.
- *Left-handed nuclei:* Nuclear theorists have predicted that triaxial nuclei with odd numbers of both protons and neutrons could have handedness. In particular, observing the so-called chirality would provide solid evidence for stable triaxial shapes, while also establishing handedness as a new property of nuclei. Recently, experimenters and nuclear structure theorists using 3D tilted axis cranking calculations have found evidence for handedness in odd-odd nuclei in ^{55}Cs, ^{57}La, and ^{61}Pm, N = 75 isotones (same number of neutrons) of ^{134}Pr.
- *New Theoretical Tool Ties Together Many Different Phenomena:* A new comprehensive framework, called the Generalized Parton Distributions (GPD's) has been developed that allow for the first time, to describe and relate a large variety of complex high-energy electromagnetic reactions to the internal quark and gluon structure of the nucleon.
- *Indicators of quark-gluon plasma formation:* Theoretical calculations using a hydrodynamic model appear to be in excellent agreement with the first and second year RHIC data on "elliptic flow." When two heavy nuclei collide, the initial fireball created in the "little bang" has the shape of an almond or more precisely, the fireball is said to be elliptically deformed. The subsequent near light-speed explosion of this 'deformed' fireball results in an anisotropy of the final transverse momentum distribution of the emitted particles. This effect is called elliptic flow. It is remarkable that the majority of the data (low momentum particles) are seen to coincide with the upper limit of the hydrodynamical calculations. This unexpected agreement suggests that a significant thermal pressure existed on a time scale too short to be explained by conventional collision dynamics, but rather it

seems plausible that the early stage of the nuclear collision might implicate the appearance of a new phenomenon.

- *Origin of elements*: Spectacular core-collapse supernovae explosions represent the violent end of a massive star's life, and create and disperse many elements – but the explosion mechanism remains elusive. Theoretical nuclear astrophysics, coupled with results from a variety of nuclear physics measurements represents the foundation of an emerging generation of sophisticated, computationally intensive models of astrophysical phenomena. For example, nuclear theorists working on the DOE Scientific Discovery through Advanced Computing (SciDAC) program on simulations of exploding stars are continuing to make rapid progress on many fronts. Neutrino transport is now being utilized in one-dimensional (spherical) models of stars. Recent progress has also been made in calculating electron-capture rates crucial to the understanding stellar collapse. Multi-dimensional stellar models are now able to explore effects such as convention induced by neutrino heating. These new computational tools could also be applied to other fields of research.

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, to 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.

Subprogram Goal

Provide a theoretical program that supports the Medium Energy, Heavy Ion, and Low Energy strategic goals, by developing models, computational techniques, interpreting data, and finding new directions for profitable investigation; provide reliable nuclear data in formats that are useful for a wide range of activities in nuclear and astrophysics research, nuclear medicine, nuclear stockpile stewardship, national security and space exploration.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
		Develop models, interpret data, and find new research directions relevant to the Nuclear Physics mission, and publish results. At the National Nuclear Data Center, complete database migration project, performing a generational step to a modern relational database management system.

Funding Schedule

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Theory Research					
University Research	10,923	11,045	11,811	+766	+6.9%
National Laboratory Research	7,618	6,590	9,165	+2,575	+39.1%
Scientific Computing (SciDAC)*	2,000	2,000	2,000	0	0%
Subtotal Theory Research	20,541	19,635	22,976	+3,341	+17.0%
Nuclear Data Activities	4,788	5,010	5,162	+152	+3.0%
Total, Nuclear Theory	25,329	24,645	28,138	+3,493	+14.2%

*In FY 2002 funding for the NP portion of the SciDAC program was distributed between University ($854,200) and National Laboratory Research ($1,145,800).

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Theory Research	**20,541**	**19,635**	**22,976**
▪ **University Research**	**10,923**	**11,045**	**11,811**

The research of about 170 university scientists and 80 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. *Support increases by 4.7% from FY 2003, after accounting for shifts of $241,000 in grants from the Medium Energy and Low Energy subprograms.*

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.

▪ **National Laboratory Research**	**7,618**	**6,590**	**9,165**

Research programs are supported at six National Laboratories (ANL, BNL, LANL, LBNL, ORNL and TJNAF). *The increase in the request for Nuclear Theory in FY 2004 is in direct response to the recommendation in the 2002 Nuclear Science Advisory Committee Long Range Plan. These increased funds will be used to hire additional theorists to work on high priority topics and to expand computing. It is proposed that redirection of $2,155,000 to theory will be made in FY 2003 in order to respond effectively to this recommendation. When this is taken into account there is an effective 4.8% increase in funding in FY 2004 compared to FY 2003.*

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

- 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 2002	FY 2003	FY 2004
▪ **Scientific Computing**	**2,000**	**2,000**	**2,000**

The Scientific Discovery through Advanced Computing (SciDAC) program is an Office of Science program to address major scientific challenges that require advances in scientific computing using terascale resources. An effort managed by the High Energy and Nuclear Physics (HENP) programs 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 FY 2001 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 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.

	FY 2002	FY 2003	FY 2004
Nuclear Data	**4,788**	**5,010**	**5,162**

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 2002	FY 2003	FY 2004
Total, Nuclear Theory	**25,329**	**24,645**	**28,138**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
University Research	
▸ FY 2004 funding level is increased by 4.7% compared to FY 2003 once shifts of $241,000 in grants from the Medium Energy and Low Energy subprograms are taken into account. This provides increased funding for students and focused funding for priority research that was identified in the NSAC 2002 Long Range Plan for Nuclear Science.	+766
National Laboratory Research	
▸ FY 2004 funding level is increased by 4.8% compared to FY 2003, once proposed shifts of $2,155,000 in FY 2003 are accounted for. This addresses the need for enhanced theoretical efforts to interpret the results obtained at our new facilities. Such enhanced support was strongly recommended in the NSAC 2002 Long Range Plan for Nuclear Science.	+2,575
Nuclear Data	
▸ FY 2004 funding level is increased by 3.0% compared to FY 2003 to enhance efforts to effectively disseminate nuclear data needed for basic and applied research.	+152
Total Funding Change, Nuclear Theory	+3,493

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
General Plant Projects	6,649	6,560	6,640	+80	+1.2%
Accelerator Improvement Projects	5,450	5,400	5,800	+400	+7.4%
Capital Equipment	29,617	30,220	27,727	-2,493	-8.2%
Total, Capital Operating Expenses	41,716	42,180	40,167	-2,013	-4.8%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp- riations	FY 2002	FY 2003	FY 2004 Request	Accept- ance Date
STAR EM Calorimeter	8,600	4,997	3,300	303	0	FY 2003
STAR EM Calorimeter Enhancement	4,700	0	0	2,400	2,300	FY 2004
G0 Experiment Detector	3,965	3,906	59	0	0	FY 2002
GRETINA gamma-ray detector	15,000	0	0	0	1,000	TBD
Fundamental Neutron Physics Beamline	9,800	0	0	0	500	FY 2011
Total, Major Items of Equipment		8,903	3,359	2,703	3,800	

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 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 and provides the science base in support of the Energy Policy Act of 1992.

Overview:

The Biological and Environmental Research (BER) program supports fundamental research in climate change, environmental remediation, genomics, proteomics, radiation biology, and medical sciences. BER supports leading edge research facilities used by public and private sector scientists across the range of BER disciplines. BER works with other federal agencies to coordinate research across all of its programs. BER validates its long-range goals through its advisory committee, the Biological and Environmental Research Advisory Committee (BERAC).

The Opportunity:

With the 21st Century dawns what most have called the "biological century" – an era when advances in biology, spurred by achievements in genomic research, including the sequencing of the human genome, will bring revolutionary and unconventional solutions to some of our most pressing and expensive challenges in health, energy, the environment, and national security. We will understand how living organisms interact with and respond to their environments so well that we will be able to use biology to produce clean energy, remove excess carbon dioxide from the atmosphere, and help clean up the environment. Our understanding of global climate change and our ability to predict climate over decades to centuries will enable us to develop science based solutions to reduce and minimize the impacts of climate change and to better plan for our Nation's future energy needs. BER will lead the way in discovering innovative approaches along unconventional paths to energy independence and environmental cleanup.

The Challenges:

Understanding and predicting climate – Can we understand the factors that determine Earth's climate well enough so that we can predict climate decades to centuries in the future? Advanced climate models are needed to describe and predict the roles of oceans, the atmosphere, ice and land masses on climate. So too, the role of clouds in controlling solar and thermal radiation onto and away from the Earth needs to be understood since it is the single largest uncertainty in climate prediction. Moreover, the impacts of excess carbon dioxide in the atmosphere from human sources, including energy use, on Earth's climate and ecosystems need to be determined and possible mitigation strategies developed.

A cleaner environment – Microbes have a remarkable capacity to thrive in almost every environment imaginable, even when heavily contaminated. Can we use Nature's own solutions to clean up sites contaminated from years of weapons research? These solutions seem ever closer as we study the molecular details of nature's own clean up strategies.

Technology for a healthier Nation – At the crossroads of the physical and biological sciences is the promise of remarkable technology for tomorrow's medicine. Developments in imaging technology have the potential to revolutionize all of medical imaging with increases in sensitivity, ease of use, and patient comfort. Technological wonders are on the horizon, like an artificial retina that will give vision to the blind.

A new biology – Can we understand the workings of biological systems well enough so that we can use Nature's own principles of design to solve energy and environmental challenges? Understanding nature's array of multi protein molecular machines, each with exquisitely precise and efficient functions and controls, will enable us to use and even redesign these molecular machines to address DOE and National needs.

The Investment Plan:

BER will continue its investments in core technologies and fundamental science needed to address these daunting challenges. We believe that the most important scientific advances in the 21st century will occur at the interfaces between scientific disciplines such as biology, physics, chemistry, engineering, and information science.

Of highest priority will be the development of a new research infrastructure needed to understand fundamental biological principles underlying the function and control of biological systems. A combination of novel, state-of-the-art user facilities coupled with large, well-integrated, interdisciplinary research teams will form the basis of a new approach for studying complex biological systems and for using those systems to solve problems in energy and the environment. Our ability to predict climate on global and regional scales and to develop strategies for the removal of excess carbon dioxide, a contributor to global warming, from the atmosphere will depend on the continued development of novel research tools and a close integration of experimental and computational sciences research. Because of DOE's diverse capabilities across a range of scientific disciplines, from engineering to chemistry to biology to computing, continued investments in advanced medical concepts will continue to provide the medical community with novel devices and technologies to improve our Nation's health.

The Benefits:

Basic biological and environmental research has broad impacts on our health, our environment, and our energy future. An ability to predict long-range and regional climate enables effective planning for future needs in energy, agriculture and land and water use. Biotechnology solutions are possible for DOE energy, environmental, and national security challenges by understanding complex biological systems and developing computational tools to model and predict their behavior. Understanding the global carbon cycle and the associated role and capabilities of microbes can lead to solutions for reducing carbon dioxide concentrations in the atmosphere. Biological solutions can be developed to help clean up metals and radionuclides contaminating former DOE weapons sites. Both normal and abnormal health - from development to cancer to brain function – can be understood using radiotracers and advanced imaging instruments. Understanding the biological effects of low doses of radiation can lead to the development of science-based health risk policy to better protect workers and citizens.

How We Work:

BER uses a variety of mechanisms for conducting, coordinating, and funding biological and environmental research. BER is responsible for planning and prioritizing all aspects of supported research, for conducting ongoing assessments to ensure a comprehensive and balanced portfolio that addresses DOE and National science needs, and for coordinating its research programs with those of other federal agencies. BER regularly seeks advice on its research programs from the scientific community and from its diverse stakeholders. BER supports research at national laboratories, universities, research institutes, and in private companies and maintains a strong research infrastructure across the biological and environmental sciences most relevant to the BER program.

Advisory and Consultative Activities:

To ensure that resources are allocated to the most scientifically relevant and promising research, BER actively seeks external input using a variety of advisory bodies. BER regularly compares its programs to the scientific priorities recommended by the BERAC and by the standing committees created by the Office of Science and Technology Policy. BER staff and BERAC both interact with and receive feedback from other programs and advisory committees across the Department including, Advanced Scientific Computing Research, Basic Energy Sciences, Environmental Management, Energy Efficiency and Renewable Energy, Nuclear Energy, Fossil Energy, and the National Nuclear Security Administration. BER program coordination across federal agencies also benefits from international and interagency working groups such as those of the International Human Genome Project, the U.S. Global Change Research Program, and the National Institutes of Health Bioengineering Consortium. Finally, BER consults regularly with groups like JASON and The Washington Advisory Group (WAG), involving physicists, mathematicians, engineers, etc., to receive feedback on BER program elements such as the Atmospheric Radiation Measurement (ARM) program, climate change prediction activities, the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), and the Human Genome program.

Facility Operations Reviews:

BER facility operations are monitored by peer reviews and user feedback. BER facility operations have also been reviewed by BERAC and by an Office of Science and Technology Policy (OSTP) interagency working group evaluating structural biology user facilities. The Office of Science's Construction Management Support Division has reviewed BER's Joint Genome Institute. BER manages these facilities in a manner that meets user requirements as indicated by achieving performance specifications while protecting the safety of 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.

Program Reviews:

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, requested level of funding, and research facilities, 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.

At the highest level, regular reviews of individual BER program elements and of the entire BER research program are conducted by BERAC. As noted above, BER also benefits from interagency and international reviews of programs such as the Human Genome Program, the Global Change Research Program, and the structural biology research program, including reviews 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, the computational sciences, and the life sciences and aggressively pursues every opportunity to nurture collaborations at the interfaces between these scientific domains.

Planning and Priority Setting:

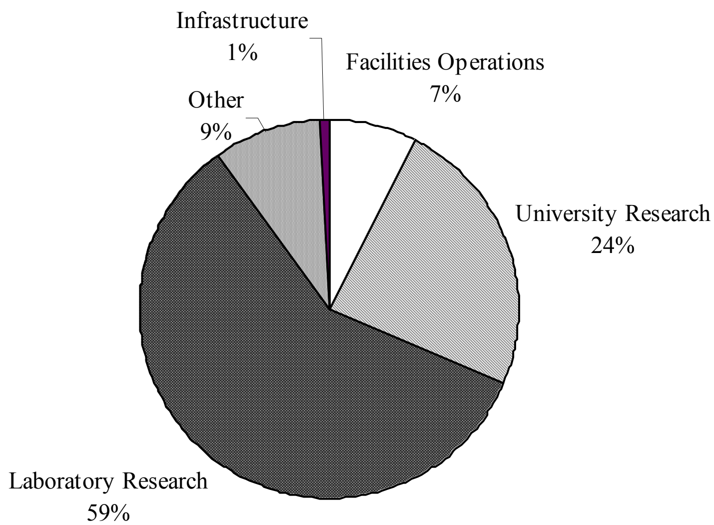
BER prides itself on supporting research and developing new research initiatives that lead the way across many fields of science and that effectively bring together many different disciplines, including biology, chemistry, engineering, computing, and the physical sciences. Peer reviews and user feedback are incorporated as BER anticipates and 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 with strong involvement of the research community.

BER planning and priority setting are also key BERAC activities and part of BER's interagency coordination. Individual BER program elements, e.g., human genome, low dose radiation research, Genomes to Life, bioremediation research, and global climate change develop long-range program plans through coordinated efforts with BERAC and with other federal agencies.

How We Spend Our Budget:

The BER budget has three major components: basic research at universities (31%); basic research at national laboratories (53%); and user facility support (6%). Research at national laboratories also includes support for high throughput DNA sequencing at the Joint Genome Institute, Atmospheric Radiation Measurement Infrastructure, Unmanned Aerial Vehicles, and other elements that represent a research infrastructure for the scientific community, and primarily university scientists. BER's user facilities include the infrastructure at synchrotron and neutron sources for structural biology and operation and equipment for the Environmental Molecular Sciences Laboratory.

BIOLOGICAL AND ENVIRONMENTAL RESEARCH
FY 2004



Research:

In FY 2004, the BER program will support fundamental research in climate change, environmental remediation, genomics, proteomics, radiation biology, and medical sciences at 223 public and private research institutions in 43 states and at 16 DOE laboratories in 10 states. This research will be conducted in 1020 different research projects by over 2275 researchers and students. In addition to the principal investigator for each research project funded by BER, individual projects typically have between 1 and 20 additional PhD-level scientists who are funded collaborators. Information on scientific collaborators is not routinely tracked.

- ***University Research:*** University researchers play a critical role in the BER program, conducting fundamental research and developing the next generation of scientists for the nation's biological and environmental research efforts. BER will continue its commitment to and dependence on scientists at the Nation's universities. In general, BER-supported research at universities and research institutions are single investigator projects. Approximately half of BER basic research funding supports university-based activities directly and indirectly. University scientists are the major scientific users at BER facilities and other enabling research infrastructure such as the ARM program.

  All research projects supported by the BER program undergo regular peer review and evaluation based on the procedures set down in 10 CFR Part 605 for the extramural grant program (http://www.sc.doe.gov/production/grants/merit.html). Peer review of BER projects is performed to provide an independent assessment of the scientific and/or technical merit of the research by peers having knowledge and expertise equal to that of the researchers whose work they review.

- ***National Laboratory Research:*** Research projects at national laboratories are more often multi-investigator team projects that take advantage of unique resources, capabilities, or facilities found at the national laboratories. Researchers at the national laboratories collaborate extensively with academic researchers supported by BER as well as with academic users of the BER facilities and research infrastructure including the Environmental Molecular Sciences Laboratory, Atmospheric Radiation Measurement, Free Air Carbon Dioxide Enhancement, and AmeriFlux sites, Natural and Accelerated Bioremediation Research Field Research Center, the Joint Genome Institute, and the structural biology user facilities at the synchrotron and neutron sources.

All research projects supported by the BER program undergo regular peer review and evaluation. BER research at the DOE Laboratories and scientific user facilities undergoes peer review and evaluation in a similar procedure to that used for university-based research

Program Strategic Performance Goals

Progress toward accomplishing BER's strategic goals will be measured by Program Strategic Performance Goals, Indicators and Annual Targets, as follows:

SC3-1: Identify and characterize the multiprotein molecular machines that carry out the biological functions of cells and determine the biochemical capabilities of complex microbial communities, information needed to develop biotechnology solutions for clean energy, carbon sequestration, and environmental cleanup.

Performance Indicator

Number of complex microbial communities and multiprotein molecular machines that can be characterized per year.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Determined DNA sequence from 41 microbes important for energy and environmental cleanup. [Exceeded Goal]	Develop methods for sequencing DNA from complex microbial communities. (SC3-1)	Determine biochemical capabilities of a complex microbial community needed to develop biological solutions for environmental cleanup. (SC3-1)

SC3-2: Determine the response of the Earth system to different levels of greenhouse gases in the atmosphere.

Performance Indicator

Climate model resolution.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
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. [Goal Met]	Improve precision of climate models – deliver a cloud submodel to reduce uncertainty in the atmospheric energy budget by 10 % and increase resolution of atmospheric/ocean submodels to 150 km & sea ice submodel to 75 km for a fully coupled climate model. (SC3-2)	Implement a climate model with new cloud model components developed using Atmospheric Radiation Measurement (ARM) data, which will be used to predict regional and global climate change. (SC3-1)
Completed analysis of physical factors that govern CO_2 and water vapor flux dynamics at AmeriFlux sites. Study identified improvements for low flux measurement, which continues to be under-estimated and may introduce bias of as much as ± 20% in estimates of net ecosystem exchange (NEE) of CO_2 for example. [Goal Met]	Document a range of net annual carbon gain in deciduous forest sites in eastern North America of 2 to 4 metric tons of carbon per hectare. (SC3-2)	Deliver quantitative estimates of net annual carbon exchange between the atmosphere and terrestrial ecosystems at five AmeriFlux sites in North America. (AmeriFlux is a network of research sites that measure exchange of CO_2, energy, and water between the atmosphere and terrestrial ecosystems.) (SC3-2)
		Establish a model terrestrial ecosystem containing simplified but hierarchical communities (higher plants, consumers of plant production, and soil microorganisms) and begin characterization of the proteome of the major species. (SC3-2)

SC3-3: Develop and demonstrate novel solutions to DOE's most challenging problems, including: 1) in situ treatment of contaminant plumes such as bioremediation and environmental reactive barriers; 2) new treatment options for complex wastes; 3) novel disposal options for complex wastes (e.g. alternative to borosilicate glass) and cost-effective contaminant plume characterization and monitoring techniques for long-term stewardship of sites; 4) improved predictive capabilities for contaminant fate and transport; and 5) basis for accurate assessment of risk factors.

Performance Indicator

Advanced environmental cleanup approaches delivered.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Radiation resistant superbug, *D. radiodurans* changes mobile uranium and technetium in ground water into an immobile state. [Goal Met]	Identify naturally occurring microbial populations responsible for transformation of metals and radionuclides at DOE contaminated sites. (SC3-3)	Quantify rates of immobilization of metals and radionuclides by natural populations of microorganisms at DOE contaminated sites and identify environmental factors regulating their community structure and function. (SC3-3)
Developed a portable immunoassay that determines the quantity and species of uranium. [Goal Met]	Field test novel, long-term monitoring systems for DOE contaminated sites that are less invasive and require minimal human resources. (SC3-3)	Use experimental results from Hanford subsurface contaminant flow and transport studies to verify model improvement. (SC3-3)

SC3-4: Develop innovative radiopharmaceuticals for diagnosis and treatment of human disease and develop novel imaging instrumentation and technologies to precisely visualize and measure biological functions, including gene expression, and more accurately detect human disease.

Performance Indicator

Number of novel imaging devices delivered.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Developed novel radiopharmaceutical tracers to image the brain in obesity and addictive disorders. [Goal Met]	Establish new infrastructure in radiochemistry to develop novel radiopharmaceuticals needed to image changes in the brains of patients with mental and neurological diseases. (SC3-4)	Develop 2-4 novel radiopharmaceuticals to be used to image the brains of patients suffering from mental, neurological diseases and cancer. (SC3-4)
Developed PET and technetium radiotracers that will be used to detect expression of specific genes. [Goal Met]	Develop technology to image gene expression in real time using *in vitro* systems – precursor of a new medical imaging tool for disease diagnosis and monitoring treatment efficacy. (SC3-4)	Develop technology to detect steady state levels of the products produced by genes in real time and complete first image of the expression of one gene using cells in culture.
Development of a low-density microelectronic array (prototype artificial retina) that was inserted into the eye of a dog. [Goal Met]	Design an artificial retina – a microelectronic array to be used for the treatment of blindness. (SC3-4)	Complete fabrication of prototype micro array for use as an artificial retina. (SC3-4)

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Development and modeling of the platform for a small biosensor for rapid diagnosis of specific infectious diseases. [Goal Met]	Design a small biosensor device for rapid diagnosis of specific infectious diseases, using tuberculosis as a model organism. This technology will have broad application including, for example, in vivo monitoring of blood glucose in diabetics. (SC3-4)	Complete fabrication of a compact device for the rapid diagnosis of tuberculosis. (SC3-4)

SC7-3: Manage facilities operations and construction to the highest standards of overall performance using merit evaluation with independent peer review. (BER)

Performance Indicator

Average operational downtime of facilities will not exceed 10% of total time scheduled, and construction and upgrades of facilities will be within 10% of baseline schedule.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Construction initiated on Laboratory for Comparative and Functional Genomics at Oak Ridge. [Goal Met]	Complete construction of Laboratory for Comparative & Functional Genomics at Oak Ridge. (SC7-1)	Begin operation of Laboratory for Comparative & Functional Genomics at Oak Ridge. (SC7-1)
Doubled capacity of the Production Genomics Facility (PGF) to sequencing 8 billion base pairs of DNA. [Exceeded Goal]	Increase capacity of Production Genomics Facility (PGF) to sequence 17 billion base pairs of DNA per year, an increase of approximately 50% from FY 2002. (SC7-1)	Begin operation of Production Genomics Facility as a user facility. (SC7-1)
Environmental Molecular Sciences Laboratory developed a new type of mass spectrometer that is 1000 times more sensitive than existing systems for identifying the proteome of organisms. [Goal Met]	Environmental Molecular Sciences Laboratory 's (EMSL) new high performance computer is fully operational. (SC7-1)	The Environmental Molecular Sciences Laboratory's 900 MHz Nuclear Magnetic Resonance (NMR) instrument will be fully operational and have an established user base. (SC7-1)
		Average operational downtime of BER facilities will not exceed 10% of total time scheduled. (SC7-1)

Program Assessment Rating Tool (PART) Assessment

The Office of Management and Budget's (OMB) PART assessment of the BER program rated the program highly for having "a well defined mission, merit-based reviews for awarding contracts and grants, and highly-regarded large project management practices." BER was rated lower for planning and results because of BER's "current lack of adequate long-term and annual performance measures" though it was acknowledged that "the program has made significant strides toward developing such measures despite the problems inherent in measuring and predicting scientific progress."

The BER program was found to be focused, well managed, and to have played a leading role in the genomics revolution. BER's coordination of research with other federal research agencies was acknowledged. The regular review of the BER program by panels of outside experts was also acknowledged. At OMB's suggestion, BER is examining its use of these outside expert panels and will identify by the end of FY 2003 ways to improve the efficiency of these reviews.

To address OMB's concern for BER's "current lack of adequate long-term and annual performance measures," BER is working with SC, the Chief Financial Officer, and OMB to reform its performance measures and goals to more accurately predict future scientific progress in a scientifically justifiable and meaningful manner.

BER LEADERSHIP AND UNIQUE ROLES

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

- Manage research on microbes for energy and the environment 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 instrumentation 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 Program Shifts

For FY 2004, BER will focus on:

- Research to create the new generation of sophisticated high-throughput technologies that are required for translating the new biology, making them widely and readily available, and using them effectively to serve the community of national laboratories, academic, and industrial researchers. Research needed to develop these technologies is currently being funded as part of the Genomes to Life program. This research will be a key component of the design and development of future facilities needed in the Genomes to Life program for conducting Systems Biology research.
- With the completion of the high quality DNA sequence of human chromosomes 5, 16, and 19, DNA sequencing capabilities at the JGI will emphasize the DNA sequencing needs of the broader research community. Sixty percent of the JGI's sequencing capacity of 1 billion base pairs per month will be available to all scientists as a user service as determined by scientific peer review of nominations for DNA sequencing targets. The remaining sequencing capacity will continue to address DOE research on microbes for energy and the environment.
- In FY 2004, BER will continue to contribute to the Administration's Climate Change Research Initiative (CCRI) to deliver information useful to policy makers. The BER contribution to the CCRI will primarily be through focused research on the carbon cycle to help resolve the North American carbon sink question –What fraction of the excess carbon dioxide emissions are taken up by the U.S. terrestrial ecosystem? BER will also contribute to the CCRI in other areas, including climate change modeling, atmospheric composition, and regional impacts of climate change.
- In FY 2004, BER will initiate new ecological research to understand how the scales of response of complex ecosystems to the environment, including their underlying causal mechanisms and pathways, are linked, ranging from the proteomes of individual species to the whole ecosystem. The focus initially will be on understanding the linkages of scales in model terrestrial ecosystems containing simplified but hierarchical communities (higher plants, consumers of plant production, and soil microorganisms). A key environmental factor such as temperature that is known to affect ecosystem functioning (e.g., carbon and nutrient cycling) will be experimentally manipulated and proteomic responses of individual species and the whole ecosystem will be measured. Advanced biologically based computational algorithms and ecosystem models will be developed to establish whether and how proteomic changes (in either single species or whole systems) explain the

responses and behavior of complex ecosystems. Tools and principles developed from this research will have broad generality and eventual application to problems in carbon sequestration, ecological risk assessment, environmental restoration and cleanup, and early detection of ecological responses to climate change and other environmental perturbations caused by energy production and use.

- 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 were transferred from the Office of Environmental Management (EM) to the Office of Science. BER manages these research activities according to Office of Science principles, with extensive input from EM.
- In FY 2003, $20,000,000 was proposed for transfer to the Department of Homeland Security to determine the DNA sequences of potential biothreat agents, to develop technologies to determine and compare the function of the genes coded for by these DNA sequences, and to develop computational tools and databases for the DNA sequencing and annotation of potential biothreat agents. These activities will be budgeted by the Department of Homeland Security in FY 2004.

Genomes to Life Research

The FY 2004 budget includes funds for the continued expansion of the Genomes to Life program—a program at the forefront of the biological revolution—a systems approach to biology at the interface of the biological, physical, and computational sciences to address DOE's energy, environment, and national security mission needs. 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 diverse biochemical capabilities, especially as they relate to potential biological solutions to DOE needs, found in populations of microbes isolated from DOE-relevant sites. In FY 2004, new capabilities will be developed for high throughput protein production and diverse imaging capabilities needed to characterize multiprotein complexes and gene regulatory networks and capabilities in high throughput proteomics will be enhanced well beyond current potential. Also in FY 2004, research and development that underpins future facilities needed by the Genomes to Life program will be conducted. Antiterrorism-related activities have been transferred to the Department of Homeland Security.

Climate Change Science Program

In 2003, the Administration launched a new Climate Change Research Initiative (CCRI) that is intended to focus research on areas where substantial progress in understanding and predicting climate change, including its causes and consequences, is likely over the next five years. DOE, in conjunction with its interagency partners, including NSF, NASA, NOAA, USDA, Interior, and EPA, will continue to focus its Climate Change Research in specific areas relevant to the CCRI. These areas include climate modeling, climate processes, carbon cycling, atmospheric composition, and regional impacts. The deliverables from this research will be targeted at information useful to policy makers. In FY 2004, DOE will also continue to contribute research to the CCRI research area for which additional funding was requested by the Administration for DOE in FY 2003, specifically carbon cycle research to resolve the magnitude and location of the North American carbon sink.

Scientific Discovery through Advanced Computing (SciDAC)

The Scientific Discovery through Advanced Computing (SciDAC) activity is a set of coordinated investments across all Office of Science mission areas with the goal of achieving breakthrough scientific advances through computer simulation that were impossible using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. By exploiting advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-discipline collaboration among the scientific disciplines together with computer scientists and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can fully exploit terascale computing and networking resources. The program will bring simulation to a parity level with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate prediction, plasma physics, particle physics, astrophysics and computational chemistry.

Scientific Facilities Utilization

The Biological and Environmental Research request includes funds to maintain support of the Department's major scientific user facilities. Facilities include structural biology research beam lines at the synchrotron light sources and neutron 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 to maintain support for and operation of these facilities.

BER will maintain and operate EMSL and the structural biology user facilities so that the unscheduled operating downtime will be less than 10%, on average, of total scheduled operating time.

User Statistics for the Environmental Molecular Sciences Laboratory[a]

	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004
Maximum hours	4,365	4,365	4,365	4,365	4,365
Scheduled hours	3,130	3,130	4,275	4,365	4,365
Unscheduled Downtime	5%	5%	5%	5%	5%

[a] Scientists use or remotely access some of the more than 100 instrumentation/computer systems in the EMSL 24 hours/day while other instruments are used only 10-12 hours/day. Maximum hours identified above are therefore based on a 12-hour day average estimate. Scheduled hours and downtime for each of the 100 instrument systems are also unique. As a result, the scheduled hours identified above are based on a 10-hour day average estimate. None of the major instrument systems within the EMSL have experienced any significant unscheduled downtimes.

User statistics for BER structural biology user facilities at DOE neutron and light sources are included as part of the user statistics collected and reported by the Basic Energy Sciences program and are not repeated here.

Construction and Infrastructure:

BER will meet the cost and schedule milestones for construction of facilities and major items of equipment with 10% of baseline estimates.

Construction of Laboratory for Comparative and Functional Genomics at Oak Ridge National Lab

	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004
Total Project Cost	$520,000	$2,495,000	$11,405,000	0	0
Cost Variance	0	0	0	0	0
Schedule Variance	0	0	+$10,000,000[a]	-$10,000,000[a]	0
Major Milestones Completed	-	-	Construction started in 3rd quarter	Construction to be completed in 4th quarter	-

[a] Full funding for the construction of the Laboratory for Comparative and Functional Genomics was provided in FY 2002. By the end of FY 2003 construction of the Laboratory will be completed on schedule. This new facility will replace a 50-year old animal facility with rapidly escalating maintenance costs that is still in use at Oak Ridge National Laboratory.

Funding for capital equipment is increased to provide the capabilities essential for initiating the Genomes to Life program. For all other BER activities the capital equipment is held at near the FY 2003 level.

The BER program, as part of its responsibilities as landlord for the Pacific Northwest National Laboratory (PNNL) and the Oak Ridge Institute for Science and Education (ORISE), provides funding for the general plant projects (GPP) and general plant equipment (GPE). In addition to the general-purpose line item projects funded out of the Science Laboratories Infrastructure program, GPP and GPE represent the capital investment funding provided by the Department for the general laboratory infrastructure. This ensures that the PNNL and ORISE infrastructures will continue to enable the Department's mission activities at these sites.

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 their 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 2003. This number includes some 600 graduate students and post-doctoral investigators who conducted their research at the EMSL in FY 2002. BER will continue its support for graduate students and post-doctoral investigators in FY 2004. The number of graduate students and post-doctoral investigators will remain approximately at the FY 2003 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 post-doctoral investigators. The graduate students and post-doctoral investigators are supported by resources from a wide variety of sponsors, including BER, other Departmental research programs, other federal agencies, and U.S. and international private institutions. Graduate students and post-doctoral investigators at the synchrotron light sources are included in the Basic Energy Sciences (BES) user facility statistics and are thus not included here. As noted above, some 600 graduate students and post-doctoral investigators conducted their research at the EMSL in FY 2002.

BER will continue its commitment to and dependence on research scientists at the Nation's universities. Approximately half of BER basic research funding directly or indirectly 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.

DOE-BER Human Capital

	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004
# University Grants	532	579	628	630[a]	630[a]
Size / Duration	$302,000/yr	$287,000/yr	$309,000/yr	$300,000/yr[a]	$300,000/yr[a]
	3 years	3 years	3 years	3 years	3 years
# Lab Projects	379	397	392	395[a]	400[a]
# Permanent PhDs[b]	1310	1370	1427	1491[a]	1489[a]
# Postdocs[c]	251	274	357	373[a]	372[a]
# Graduate Students[c]	438	443	491	481[a]	488[a]
# PhDs awarded[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]

[a] Estimated. Information on the number of research projects funded, the size of those projects, or the number of personnel involved cannot be known prior to the receipt of research applications or proposals, their peer review, and the completion of funding decisions.

[b] Estimated. Information is not readily available on the total number of permanent PhDs associated with each research project. In addition to the principal investigator for each research project funded by BER, individual projects typically have between 1 and 20 additional PhD-level scientists who are funded collaborators. Information on scientific collaborators is not routinely tracked.

[c] Estimated for national laboratory projects.

[d] Information is not available on the number of PhDs awarded as a result of BER funded research at universities or national laboratories. Data will be collected in the future.

Funding Profile

(dollars in thousands)

	FY 2002 Comparable Appropriation	FY 2003 Request	FY 2004 Request	$ Change	% Change
Biological and Environmental Research					
Life Sciences	186,384	190,878	201,408	+10,530	+5.5%
Climate Change Research	125,847	137,959	142,959	+5,000	+3.6%
Environmental Remediation	111,849	109,530	109,320	-210	-0.2%
Medical Applications and Measurement Science	118,640	45,848	45,848	0	--
Subtotal, Biological and Environmental Research	542,720	484,215	499,535	+15,320	+3.2%
Construction	11,405	0	0	0	--
Total, Biological and Environmental Research	554,125[abcd]	484,215[b]	499,535	+15,320	+3.2%

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 $12,972,000 which was transferred to the SBIR program and $776,000 which was transferred to the STTR program.

[b] Excludes $2,128,000 in FY 2002 and $20,000,000 in FY 2003 and FY 2004 for Homeland Security activities that are funded in a separate Department of Homeland Security budget.

[c] Excludes $249,000 for the FY 2002 rescission contained in Section 1403 of P.L. 107-226 Supplemental Appropriations for further recovery from the response to terrorist attacks on the United States.

[d] Excludes $50,000 transferred to Safeguards and Security for a FY 2002 reprogramming.

Funding By Site[a]

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	23,545	19,245	19,717	+472	+2.5%
Sandia National Laboratories	5,334	3,757	5,846	+2,089	+55.6%
Albuquerque Operations Office	900	850	850	0	--
Total, Albuquerque Operations Office	29,779	23,852	26,413	+2,561	+10.7%
Chicago Operations Office					
Ames Laboratory	830	512	555	+43	+8.4%
Argonne National Laboratory – East	24,446	22,970	23,295	+325	+1.4%
Brookhaven National Laboratory	23,749	16,248	14,964	-1,284	-7.9%
Chicago Operations Office	137,618	46,146	50,394	+4,248	+9.2%
Total, Chicago Operations Office	186,643	85,876	89,208	+3,332	+3.9%
Federal Energy Technology Center	625	0	0	0	--
Idaho Operations Office					
Idaho National Engineering & Environmental Laboratory	2,428	2,205	3,400	+1,195	+54.2%
Idaho Operations Office	14,242	12,552	12,283	-269	-2.1%
Total, Idaho Operations Office	16,670	14,757	15,683	+926	+6.3%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	72,102	42,786	53,055	+10,269	+24.0%
Lawrence Livermore National Laboratory	27,539	28,199	36,502	+8,303	+29.4%
Stanford Linear Accelerator Center	4,435	5,550	3,675	-1,875	-33.8%
Oakland Operations Office	54,058	38,386	47,293	+8,907	+23.2%
Total, Oakland Operations Office	158,134	114,921	140,525	+25,604	+22.3%

[a] On December 20 2002, the National Nuclear Security Administration (NNSA) disestablished the Albuquerque, Oakland, and Nevada Operations Offices, renamed existing area offices as site offices, established a new Nevada Site Office, and established a single NNSA Service Center to be located in Albuquerque. Other aspects of the NNSA organizational changes will be phased in and consolidation of the Service Center in Albuquerque will be completed by September 30, 2004. For budget display purposes, DOE is displaying non-NNSA budgets by site in the traditional pre-NNSA organizational format.

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Oak Ridge Operations Office					
Oak Ridge Inst. For Science & Education	5,850	4,761	4,550	-211	-4.4%
Oak Ridge National Laboratory	58,549	37,495	38,448	+953	-2.5%
Thomas Jefferson National Accelerator Facility	832	500	0	-500	-100.0%
Oak Ridge Operations Office	869	352	352	0	--
Total, Oak Ridge Operations Office	66,100	43,108	43,350	+242	+0.6 %
Richland Operations Office					
Pacific Northwest National Laboratory	86,047	77,677	81,105	+3,428	+4.4%
Richland Operations Office	100	0	0	0	--
Total, Richland Operations Office	86,147	77,677	81,105	+3,428	+4.4%
Savannah River Operations Office					
Westinghouse Savannah River	239	0	0	0	--
Savannah River Operations Office	8,754	6,326	8,015	+1,689	+26.7%
Total, Savannah River Operations Office	8,993	6,326	8,015	+1,689	+26.7%
Washington Headquarters	1,034	117,698	95,236	-22,462	-19.1%
Total, Biological and Environmental Research	554,125 [abcd]	484,215 [b]	499,535	+15,320	+3.2%

[a] Excludes $12,972,000 which was transferred to the SBIR program and $776,000 which was transferred to the STTR program.

[b] Excludes $2,128,000 in FY 2002 and $20,000,000 in FY 2003 and FY 2004 for Homeland Security activities that are funded in a separate Department of Homeland Security budget.

[c] Excludes $249,000 for the FY 2002 rescission contained in Section 1403 of P.L. 107-226 Supplemental Appropriations for further recovery from the response to terrorist attacks on the United States.

[d] Excludes $50,000 transferred to Safeguards and Security for a FY 2002 reprogramming.

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, Carbon Sequestration in Terrestrial Ecosystems (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 structure 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.

Climate change research 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 and international 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 methods for 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 research community.

PNNL provides the lead scientist for the Environmental Meteorology Program, the G-1 research aircraft, and expertise in environmental 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.

SNL conducts computational and biological research in support of the Genomes to Life research program.

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 SSRL 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 223 institutions, including colleges/universities, private industry, and other federal and private research institutions located in 43 states.

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. For example 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 program. Academic investigators are also 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 Measures

The goal of the Life Sciences subprogram is to deliver fundamental knowledge of biological systems that can be used to address DOE needs in clean energy, carbon sequestration, and environmental cleanup. Fundamental research is supported in structural biology, genomics, and the health effects of low dose radiation. Human, animal, and microbial DNA sequencing is used to understand the genetic and environmental basis of normal and abnormal biological function, from human genes that make some people more sensitive to the adverse effects of low doses of radiation to the biochemical capabilities of complex microbial communities that could be used to produce clean energy or sequester atmospheric carbon dioxide. Scientific tools and resources are developed and made widely available for determining protein structures and genomic DNA sequences and for understanding the structure, function, and regulation of multiprotein complexes from DOE-relevant organisms – information that can then be used to develop biotechnology solutions for DOE needs. Finally, low dose radiation research provides knowledge underpinning rigorous, cost-effective standards to protect the health of cleanup workers and the public and for science-based decisions on DOE site cleanup. In FY 2003 $20,000,000 related to genomic analysis of potential biothreat agents was transferred to the Department of Homeland Security.

BER supports research in five areas of the Life Sciences: structural biology; low dose radiation; molecular/systems biology; human genome; and biological research.

- BER develops and supports user facilities for the Nation's structural biologists at synchrotron, nuclear magnetic resonance (NMR), and neutron sources. BER also determines the structures of proteins important for the bioremediation of metals and radionuclides or of proteins that are involved in the repair of DNA damage.
- BER supports research on the biological effects of low doses of ionizing radiation and works closely with scientists, regulators, and the public to ensure that the research results are available to develop a better scientific basis for adequately protecting people from the adverse effects of ionizing radiation.
- BER supports systems biology research in the Genomes to Life program by developing the experimental and, together with the Advanced Scientific Computing Research program, computational resources, tools, and technologies needed to understand the complex behavior of complete biological systems – from single microbes to complex microbial communities. This information can be used to develop innovative solutions for energy production, waste cleanup, and carbon management.
- BER takes advantage of the remarkable high throughput and cost-effective DNA sequencing capacity it developed as part of the International Human Genome Project to meet future DNA sequencing needs of DOE and other agencies. BER also develops resources, tools, and technologies needed to analyze and interpret DNA sequence data from entire organisms and to study the ethical, legal, and social implications (ELSI) of information and data resulting from genome projects.

- BER develops resources, tools, and technologies to understand the function of human genes that it identifies as part of the International Human Genome Project using model organisms such as the mouse, *Fugu* (the puffer fish), and *Ciona* (the sea squirt).

The Life Sciences subprogram provides fundamental knowledge building to long-term outcomes that underpin the Program Strategic Performance Goals and the Office of Science's Strategic Objectives. Periodic retrospective analysis will be employed to evaluate the accumulation of knowledge and validate specific outcomes. This program was reviewed as part of a BERAC review of the entire BER program in FY 2001. The next scheduled comprehensive review of the Life Sciences subprogram by BERAC will be in FY 2004. The following are recent scientific accomplishments that highlight program progress.

- *First Tree Genome to be Sequenced.* The genome of *Populus balsamifera* ssp. *trichocarpa,* commonly known as the black cottonwood, a species of Poplar tree will be the first tree genome ever sequenced. Scientists working on tree genetics and tree productivity and product utilization are highly enthusiastic about the sequencing of this tree species because it represents an important first step in understanding the genome of a common, commercially important tree species with potential impacts that could include improved carbon sequestration and biomass for energy. This effort is being led by a consortium of scientists from the University of Washington, Oregon State University, Pennsylvania State University, the British Columbia Genome Sequence Center, the Swedish University of Agricultural Sciences, the National Center for Genome Research in New Mexico, the DOE Joint Genome Institute (JGI), the Oak Ridge National Laboratory, and other institutions. The sequencing will be carried out at DOE's high throughput DOE sequencing facility, the JGI.
- *Pufferfish Helps Scientists Understand the Human Genome.* The first public assembly of an animal genome, the genome of the Japanese pufferfish *Fugu rubripes,* has been completed by the DOE JGI. Although the *Fugu* genome contains essentially the same genes and regulatory sequences as the human genome, it carries those genes and regulatory sequences in approximately 365 million bases as compared to the 3 billion bases that make up human DNA. With far less so-called "junk DNA" to sort through, the information can then be used to help identify genes and regulatory sequences in the human genome. This effort was led by an international research consortium that included the JGI, the Singapore Biomedical Research Council's Institute for Molecular and Cell Biology, the Human Genome Mapping Resource Centre of the United Kingdom's Medical Research Council, the Cambridge University Department of Oncology, and the Institute for Systems Biology in Seattle, Washington. The consortium's sequencing efforts were bolstered by two US companies, Celera Genomics of Rockville, Maryland and Myriad Genetics, Inc. of Salt Lake City, Utah.
- *First ever DNA sequence of an algae.* The genomic DNA sequence of a unicellular green algae has been determined by the JGI – the first algae to be sequenced. Chlamydomonads have a 100 million base pair genome (compared to 3 billion for humans and 365 million for the *Fugu* described above) and are a genus of unicellular green algae (Chlorophyta) found nearly everywhere - in soil, fresh water, oceans, and even in snow on mountaintops. Algae in this genus have a cell wall, a chloroplast for photosynthesis, an "eye" that perceives light, and two flagella with which they can swim using a breast-stroke type motion. More than 500 different species of Chlamydomonas have been described. The most widely used laboratory species is *Chlamydomonas reinhardtii.* DOE is interested in *Chlamydomonas* because of its widespread global distribution and its ability to carry out photosynthesis, the most powerful biological technology for carbon dioxide capture from the atmosphere.

- *First DNA sequence of a marine diatom.* The first ever genomic DNA sequence of a marine diatom, *Thalassiosira pseudonann*, has been determined by the JGI. Diatoms, or marine phytoplankton, are important model organisms for carbon sequestration and are found in all of Earth's oceans. They display an incredible and intriguing variety of shapes and are major players in the Earth's carbon cycle responsible for much of the ocean's ability to move carbon dioxide captured in the near surface regions by photosynthesis to deep ocean compartments. The shapes, growth rates, and carbon management processes of diatoms are all under genetic control and could be exploited to enhance its carbon processing capabilities as a step towards partial mitigation of global warming. Additionally, the silicate shells of many diatoms are engineering and material science marvels and could provide important insights for nanoscience activities.
- *JAZZing up genomes.* Because of the sequencing process, the DNA sequences of organisms large and small are determined in hundreds or thousands of small pieces. A new graphical algorithm, JAZZ, has been developed for stitching these pieces back together into a complete DNA sequence. JAZZ has been used at the JGI to put together the genomes of many microbes, a fungal genome, the genomes of the sea squirt C*iona intestinalis* and the pufferfish *Fugu rubripes*.
- *Another record-breaking year of microbial DNA sequencing.* The JGI has again surpassed expectations in microbial DNA sequencing in FY 2002 by determining high quality draft sequences of 41 microbes important to DOE needs in energy, environmental cleanup, and counter terrorism. Twelve of these organisms are pathogens or their close genetic relatives that were sequenced as part of a coordinated interagency effort to quickly characterize as many potential threat agents as possible.
- *International Scientists Celebrate at Sea Squirt Genome Jamboree*. Fifty scientists from around the world gathered in San Francisco to celebrate, by staying glued to their computers to analyze the DNA sequence of *Ciona intestinalis*, a sea squirt. *Ciona* is an organism with the smallest genome of any experimentally manipulable chordate and is a good system for exploring the evolutionary origins of the chordate lineage, from which vertebrates, including man, sprouted. The complete genome sequence of *Ciona* was determined by DOE's JGI and will provide a foundation for genome-scale analysis of regulatory networks through development. Genes that have survived in humans since the sea squirt's evolution have surely been preserved for good reasons. By comparing the human genome to the genomes of different creatures, researchers can pinpoint which genes have survived hundreds of millions of years of evolution. Those that have survived throughout evolution are likely to have important functions. In other words, they compare these animal genomes to the human genome to see the similarities and differences—and eventually discover the secrets of evolution and disease.
- *First Call for Candidate Microbes for DNA Sequencing*. DOE's JGI will now be available as a resource to all scientists for determining the DNA sequences of microbes or communities of microbes relevant to DOE mission needs including waste remediation, carbon management, and energy production. Microbes nominated by scientists for genomic sequencing will be prioritized by a panel of scientific experts, including representatives from the American Society for Microbiology. All DNA sequence data determined by the JGI will be publicly available to all scientists. This call for nominations for DNA sequencing at the JGI is the first in what is anticipated to be an ongoing series of public calls for DNA sequencing that will effectively make the JGI's considerable DNA sequencing capabilities available to scientists as a public resource.

- *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.

Subprogram Goals

Identify and characterize the multiprotein molecular machines that carry out the biological functions of cells and determine the biochemical capabilities of complex microbial communities, information needed to develop biotechnology solutions for clean energy, carbon sequestration, and environmental cleanup.

Performance Indicator

Number of complex microbial communities and multiprotein molecular machines that can be characterized per year.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
(Structural Biology – Basic Research)	(Structural Biology – Basic Research)	(Structural Biology – Basic Research)
New research emphasis in Structural Biology basic research. First awards given based on competitive peer review. [Goal Met]	Develop one new computational model 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.	Develop two new 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. Demonstrate accuracy of new model from FY 2003 by experimentally determining the fraction of proteins known to interact with these complexes that are correctly predicted by the model.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
(Microbial Genomics) Determined high quality draft sequences of 41 microbes important to DOE needs in energy and environmental cleanup. [Exceeded Goal]	(Microbial Genomics) Draft genomic sequence of more than 30 microorganisms of high DOE relevance and scientific research; improve the computational tools for predicting gene function; and develop methods for sequencing unculturable microbes and microbial consortia.	(Microbial Genomics) Determine the frequency of lateral gene transfer among 5 different groups of microbes, improve the efficiency of computational tools for predicting the function of newly identified microbial genes by 50%, and develop new strategies for the rapid comparison of closely related microbial DNA sequences that are twice as efficient as current methods
(Carbon Sequestration Research) The first ever genomic DNA sequence of a marine diatom, *Thalassiosira pseudonann*, has been determined by the JGI, well ahead of the original schedule for completion. [Goal Met]	(Carbon Sequestration Research) Complete DNA sequence of a member of the genus *Populas* (trees like poplar, aspen, etc.). In addition, determine the draft DNA sequence of *Thalassiosira*, a diatom important in oceanic sequestration.	(Carbon Sequestration Research) Identify genes and proteins in the poplar that are important for carbon utilization and initially characterize microbes that live in the poplar rhizosphere.
(Genomes to Life) New research program in FY 2002.	(Genomes to Life) In conjunction with ASCR and using data produced by BER and BES-sponsored microbial cell project researchers, develop new computational tools for the analysis and simulation of biological processes. 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.	(Genomes to Life) Produce 1000 distinct proteins in quantities of 2 milligrams each in highly purified form and use those proteins to develop tags that enable detection and imaging of 500 of these molecules. These capabilities will be used to address the following GTL goals: (1) imaging the molecular machines of life; (2) imaging to characterize gene regulatory networks; and (3) imaging to characterize complex microbial communities in model and natural environments at the molecular level.

Characterize the biological effects of low doses of ionizing radiation (less than annual DOE exposure limit) to assist policy makers in developing science-based health protection standards to protect DOE cleanup workers and the public and to strengthen the scientific basis for making decisions on radiation exposure limits for DOE site cleanup operations.

Performance Indicator

Eighty percent of all new research projects will be peer reviewed and deemed excellent and relevant, and ongoing projects will be subject to triennial peer review with merit evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
(Low Dose Radiation Research)	(Low Dose Radiation Research)	(Low Dose Radiation Research)
BERAC report (March 2001) states that "the program has gotten off to an excellent start and is funding a number of scientifically sound and important projects."	Research results will be incorporated into the National Academy of Sciences Biological Effects of Ionizing Radiation VI report.	By the end of FY 2004, the program will demonstrate for the first time the effects of ionizing radiation on neighbors of irradiated cells in vivo.

Develop high throughput methods for rapidly predicting, characterizing, and understanding the control and functions of genes identified from genomic DNA sequencing.

Performance Indicator

DNA base pairs sequenced per year.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
(Human Genome)	(Human Genome)	(Human Genome)
The first public assembly of an animal genome, the genome of the Japanese pufferfish *Fugu rubripes,* has been completed by the DOE JGI. With far less so-called "junk DNA" to sort through, the information can then be used to help identify genes and regulatory sequences in the human genome. [Goal Met] A new graphical algorithm, JAZZ, has been developed for stitching small pieces of DNA sequence back together into a complete DNA sequence. JAZZ has been used at the JGI to put together the genomes of many microbes, a fungal genome, the genomes of the sea	Establish at least 30 diverse collaborations for high throughput DNA sequencing with scientists outside the JGI and with programs at other federal agencies.	Produce 12 billion base pairs of high quality DNA sequence at the JGI. Approximately 7.2 billion base pairs of the total will be genomes for outside users based on a peer-review selection process. The remaining sequencing capacity will be used to complete the draft sequence and assembly of the *Xenopus* (frog) genome, a model organism for the Human Genome Project, that will contribute to understanding human development.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
squirt *Ciona intestinalis*, and the pufferfish *Fugu rubripes*. [Goal Met] As of July 2002 the Department of Energy' Joint Genome Institute (JGI) has completed the high quality sequencing of human chromosome 19 and approximately 80% of human chromosome 16. The JGI has also produced seven billion bases of sequences completing the draft sequencing of *Fugu* (the pufferfish) and Ciona (the sea squirt) as its contribution to the Human Genome Program. [Goal Met]		

Manage all BER facility operations to the highest standards of overall performance, using merit evaluation with independent peer review.

Performance Indicator

Average operational downtime of BER facilities will not exceed 10% of total time scheduled.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
(Structural Biology – Infrastructure) New neutron crystallography user facility opened at LANL's LANSCE. An estimated 2000 users used the structural biology instruments at the DOE national user facilities (end of year data not yet available for FY 2002). [Goal Met]	(Structural Biology – Infrastructure) More than 2,500 highly satisfied users will use the structural biology instruments at the DOE national user facilities. Ten external user groups will use the LANSCE protein crystallography station.	(Structural Biology – Infrastructure) More than 3,000 highly satisfied users will use the structural biology instruments at the DOE national user facilities.
	The installation of the new station at HFIR for use by structural biologists to determine the structures of protein complexes will be completed.	Have five structural biology user groups from outside ORNL complete experiments at the HFIR by the end of FY 2004. Add at least 4000 new structure data sets to the Protein Data Bank during FY 2004. Produce a pixel array detector, with at least 100x100 pixel size, deployed at a DOE synchrotron by the end of FY 2004 (TEC less than $1 million).

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Structural Biology	29,536	27,847	27,809	-38	-0.1%
Molecular and Cellular Biology	55,041	71,195	93,500	+22,305	+31.3%
Human Genome	90,075	76,805	64,572	-12,233	-15.9%
Health Effects	11,732	10,260	10,260	0	0%
SBIR/STTR	0	4,771	5,267	+496	+10.4%
Total, Life Sciences	186,384	190,878	201,408	+10,530	+5.5%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Structural Biology	**29,536**	**27,847**	**27,809**
▪ **Basic Research**	**12,307**	**12,547**	**12,509**

In FY 2004, BER will continue to invest in structural biology research relevant to DOE missions. In carrying out their functions within cells, proteins form complexes with other proteins (forming molecular machines) and interact with a variety of structural and regulatory molecules on which proteins carry out their functions. Understanding how molecular machines carry out their biological functions requires that we observe dynamic changes in protein structure and study protein modifications, translocations, 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 translocation.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▪ **Infrastructure Development**	**17,229**	**15,300**	**15,300**

BER develops beamlines and instrumentation at the Department's national user facilities for the Nation's structural biologists and supports access by these scientists to these experimental stations. It coordinates with the NIH and the NSF management of experimental stations at DOE synchrotrons [Advanced Photon Source (APS), Advanced Light Source (ALS), Stanford Synchrotron Radiation Laboratory (SSRL) and National Synchrotron Light Source NSLS)] and neutron beam sources [the Los Alamos Neutron Science Center (LANSCE) and High Flux Isotope Reactor (HFIR) at ORNL]. User statistics for all BER structural biology user facilities are included in BES facility user reports. BER also supports access to unique high performance mass spectrometry and nuclear magnetic resonance spectrometry user facilities at the EMSL that are used for both proteomic and structural biology research. DOE investment in structural biology facilities is having a large impact on basic research investments being made by other agencies. These facilities will be used to conduct the research described above. In addition, DOE investments in structural biology user facilities at synchrotron light sources and at the EMSL have enabled the National Institute of General Medical Sciences at the National Institutes of Health (NIH) to make a large investment (over $30,000,000 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 nine pilot projects funded by NIH include partners from DOE Laboratories and nearly all make heavy use of DOE user facilities. BER also supports development of new instrumentation that will make more effective use of the intense x-ray beams at the DOE synchrotrons. A new x-ray detector technology is being supported in cooperation with the NIH called the pixel-array detector (PAD). This technology would allow much more rapid acquisition and read-out of x-ray crystallographic data and would enable collection of complete data sets for protein structure determination in minutes, avoiding problems with decomposition of the protein crystals that occur over longer time periods. The total estimated cost for each detector is estimated at less that $1,000,000.

Molecular and Cellular Biology	**55,041**	**71,195**	**93,500**
▪ **Microbial Genomics**	**10,997**	**10,987**	**9,838**

Microbial genomics research underpins DOE research programs - Fundamental microbiology research will continue to underpin DOE's need to exploit the capabilities of microbes to address mission needs. Begun in 1994 with DOE's first sequencing of a complete microbial genome, microbial genomics research continues to provide support for individual investigator initiated projects that provide a fundamental understanding of microbes.

Microbial genomics research serves to strengthen the fundamental research foundation that underpins other BER and DOE programs, including: Genomes to Life; bioremediation research; and carbon sequestration. 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 insights 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.

Microbial genomics research includes:

Development of novel strategies to obtain and compare microbial DNA sequences. 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.

Research on microbial genomic plasticity, including the normal ability of microbes to exchange genetic information in nature. Current microbial DNA sequence data strongly suggest 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 microbial DNA sequence data and for designing novel strategies for using microbes to address DOE mission needs.

Development of bioinformatics tools for analyzing microbial DNA sequence information. More than a third of the more than 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.

In FY 2003 $2,128,000 was transferred for genomic analysis of potential biothreat agents to the Department of Homeland Security.

The research activities in this subprogram are carried out at National Laboratories, universities, and at private institutions and are selected through competitive and peer-reviewed processes.

	FY 2002	FY 2003	FY 2004
▪ **Carbon Sequestration Research**	**7,057**	**7,138**	**7,127**

Microbes and plants play substantial roles in the global cycling of carbon through the environment. In FY 2004 the program continues to leverage new genomic DNA sequence information on microbes important to the global carbon cycle by characterizing key biochemical pathways or genetic regulatory networks in these microbes. 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.

Research will also leverage the genomic DNA sequence of the poplar tree, completed in FY 2003, by developing high throughput experimental and computational methods for understanding the poplar genome and proteome, especially as related to carbon utilization. Research will also focus on microbes that live in the poplar rhizosphere (root zone) with the intent of understanding the role

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

that these microbes play in the transfer of carbon between the roots and the soil. The program will emphasize organisms and pathways that serve to increase long-term carbon storage over organisms and pathways that would serve to decrease carbon storage. A goal is to identify strategies that would lead to increased carbon storage in the poplar rhizosphere and surrounding soil, such as manipulation of the soil chemical environment to promote certain microorganisms or particular metabolic pathways.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

	FY 2002	FY 2003	FY 2004
■ **Genomes to Life**	**18,696**	**34,547**	**59,039**

Genomes to Life is a program at the forefront of the biological revolution - a systems approach to biology at the interface of the biological, physical, and computational sciences. It will take advantage of solutions that nature has already devised to solve many of our most pressing and expensive problems. It will help us design and use complex systems to produce clean energy, mitigate climate change, and clean up the environment.

This new biological era – the era of systems biology – will enable us to understand entire living organisms and their interactions with the environment. Scientists have long tried to understand the workings of individual genes or small groups of genes. This new era in biology will focus on entire networks of genes and even biological systems – small, single celled organisms at first and later more complex creatures including humans.

This dramatic advance is possible, in large part, because of the scientific and technical successes of the Human Genome Project. Information and technology now available to all scientists working on the human genome and on a growing list of other organisms from microbes to plants to mice gives us new perspectives on the inner workings of biological systems and provides opportunities to use this knowledge to solve problems confronting DOE.

Genomes to Life offers the possibility of biotechnology solutions that can give us abundant sources of clean energy yet control greenhouse gases like carbon dioxide, a key factor in global climate change, and that can help us clean up past contamination of the environment.

Genomes to Life is a comprehensive, systems-level, interdisciplinary research program at the interfaces of the biological, physical, and computational sciences. It will require development of novel capabilities for new high throughput biological research, e.g., for protein production, molecular imaging, small molecule production, and proteomics. It will involve a well integrated mix of experimental and computational science that will, in the end, enable us to predict responses of biological systems to their environments and to use that predictive capability to generate solutions to complex and expensive DOE and National challenges including –

- *Clean Energy* - Within 10 years advances in systems biology, computation, and technology may contribute to increased biology-based energy sources. In the long-term, they could contribute to energy security through a major new bioenergy industry.

(dollars in thousands)

FY 2002	FY 2003	FY 2004

- *Reduced Carbon Dioxide in the Atmosphere* - Within 10 years advances in systems biology, computation, and technology may help us understand earth's carbon cycle and design ways to enhance carbon dioxide (CO_2) capture. In the long-term, they could help us stabilize atmospheric carbon dioxide to counter global warming.
- *Cleanup of the Environment* - Within 10 years advances in systems biology, computation, and technology may lead to cost-effective ways for environmental cleanup. In the long-term, new technology could save billions in waste cleanup/disposal.

Over billions of years of evolution, nature has created a remarkable array of molecular machines and complex microbial community structures with exquisitely diverse, precise, and efficient functions and controls. The goal of Genomes to Life is to understand the nature and control of these molecular machines and of complex microbial communities so well that we can use and even redesign them to address DOE and National needs. Success in Genomes to Life will be measured by scientific breakthroughs that lead to predictive computational models for –

- Natural, multiprotein molecular machines of complex living systems.
- Complex networks that control the assembly and operation of these machines.
- The organization and biochemical capabilities of complex microbial communities.

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. This research will lead to greatly improved computational strategies, tools and resources that are central to the success of Genomes to Life and, indeed, to all of biology, and that will be developed in partnership with the Advanced Scientific Computing Research program.

The broad goals of this research are shared with other agencies, such as the National Institutes of Health, the National Science Foundation, the Department of Agriculture, the Environmental Protection Agency, 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 in the private sector and will focus on high throughput genomic-scale activities (e.g., DNA sequencing, complex computational analysis, imaging, and genomic protein-expression experimentation and analysis) that are beyond the reach of individual investigators or even small teams.

Multidisciplinary research teams funded in FY 2003 will pursue the characterization of the biochemical capabilities of microbial communities. *In FY 2004, the program will increase its emphasis on research to characterize the function and control of molecular machines and on the development of broad capabilities for large scale protein production and diverse imaging approaches for these molecular machines. In FY 2004, the program will also increase its emphasis on high throughput DNA sequencing of microbes and microbial communities. This DNA sequence information will continue to serve as the core of biological information needed to understand the*

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

control and function of molecular machines and complex microbial communities. DNA sequencing for the Genomes to Life program will be conducted at the Joint Genome Institute's Production Sequencing Facility.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

	FY 2002	FY 2003	FY 2004
▪ **Human Frontiers Science**	**1,000**	**1,000**	**0**

BER has completed its funding of the Human Frontiers Science program, an international program of collaborative research to understand brain function and biological function at the molecular level.

	FY 2002	FY 2003	FY 2004
▪ **Low Dose Radiation Research**	**17,291**	**17,523**	**17,496**

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.

BER will continue to emphasize the use of new tools such as microbeam irradiators developed in the program in prior years that enable scientists to irradiate specific parts of an individual cell such as the nucleus or the cytoplasm, the use of molecular tools such as gene and protein expression chips to describe biological responses to low doses of radiation, and the characterization of individual susceptibility to radiation.

In FY 2004, emphasis will be placed on the development and use of experimental systems that enable scientists to make a transition from the use of highly quantifiable but less relevant *in vitro* systems for studying low doses of radiation to *in vivo* systems that are more relevant to human risk from exposure to low doses of radiation but in which it has been very difficult to quantify results.

BER will continue to forge 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. Scientists will be challenged to determine if bystander effects to low doses of ionizing radiation occur *in vivo*.

(dollars in thousands)

FY 2002	FY 2003	FY 2004

- *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. Scientists will be challenged to determine if low doses of radiation induce genomic instability *in vivo*.
- *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 and extended to *in vivo* systems.
- *Endogenous versus low dose radiation induced damage* – 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. Research in this aspect of the program will be concluded by the end of FY 2004.
- *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. This has been the most difficult and challenging component of the program. In FY 2004, a comprehensive effort will be undertaken to identify innovative new research strategies that will determine the extent to which the development of biologically-based risk models for low dose radiation is a possibility. This will involve interactions between experimental and computational scientists and with scientists at regulatory agencies responsible for developing risk policy.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

- 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.
- The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

	FY 2002	FY 2003	FY 2004
Human Genome	**90,075**	**76,805**	**64,572**

In FY 2003 $13,765,000 was transferred for genomic analysis of potential biothreat agents to the Department of Homeland Security.

	FY 2002	FY 2003	FY 2004
▪ **Joint Genome Institute**	**57,200**	**57,200**	**51,480**

With the completion of the high quality DNA sequences of human chromosomes 16 and 19 in CY 2002 (with chromosome 5, DOE's share of the international effort to sequence the human genome), the Joint Genome Institute (JGI) will continue, at a reduced level, to use its DNA sequencing capacity to address the challenges of understanding the human genome, to address DOE mission needs in energy, carbon sequestration, and bioremediation, and as a resource for our Nation's scientists. *Beginning in FY 2004, the JGI will devote 60% of its sequencing capacity to peer reviewed sequencing needs of the broader scientific community, including the needs of other agencies. DNA sequencing targets will be chosen using a process of peer review of requests for sequencing submitted by individual scientists and other federal agencies. Forty percent of the JGI's DNA sequencing capacity will be used to address DOE sequencing needs, including BER programs such as carbon sequestration research and bioremediation research, and other DOE and national needs. The substantial high throughput DNA sequencing needs of the Genomes to Life Program are supported directly by the Genomes to Life Program and are not included in funds for the Joint Genome Institute.*

The JGI is a virtual research institute principally comprised of research programs at DOE national laboratories (LLNL, LANL, LBNL, PNNL, ORNL) and a significant partnership with Stanford University. The JGI's DNA sequencing factory is located in Walnut Creek, California.

	FY 2002	FY 2003	FY 2004
▪ **Tools for DNA Sequencing and Sequence Analysis**	**30,396**	**16,900**	**11,245**

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. As a result of the success in sequencing the human genome, several research activities were reduced or eliminated in FY 2003 (e.g., optical mapping of chromosomes, gene library preparation, gene sequencing, etc.). Unimaginable amounts of DNA sequencing, at dramatically increased speed and reduced cost, will still be required in the future for medical and commercial purposes and to understand the information in the DNA sequence that has already been determined. In FY 2004, BER continues research to further improve the efficiency and cost effectiveness of its

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

own DNA sequencing factory at the JGI by improving the reagents used in DNA sequencing and analysis (including genome assembly and annotation); decreasing the costs of sequencing; increasing the speed of DNA sequencing; and developing more robust computational tools for genome-wide data analysis.

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 2004, BER will continue efforts to develop high-throughput approaches for analyzing gene regulation and function.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

- **Ethical, Legal, and Societal Issues (ELSI)**................................ **2,479** **2,705** **1,847**

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 associated with the genome program. DOE's ELSI research program represents three 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 multigenic characteristics and conditions.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

A table follows displaying both DOE and NIH genome funding.

U.S. Human Genome Project Funding

	(dollars in millions)			
	Prior Years	FY 2002	FY 2003	FY 2004
DOE Total Funding (FY 87-01)	864.5	90.1	76.8	64.6
NIH Funding (FY 88-01)	2,241.6	431.0[a]	467.0 [a]	TBD
Total U.S. Funding	3,106.1	521.1	543.8	TBD

[a] Estimate from NIH.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Health Effects	**11,732**	**10,260**	**10,260**
■ **Functional Genomics Research**	**11,732**	**10,260**	**10,260**

Understanding the structure and function of the human genome. – Many individual genes, large families of genes, and the regulatory networks that control these genes have been conserved during evolution in organisms as diverse as yeast and humans. Thus, model organisms including *Fugu* (puffer fish), *Ciona* (sea squirt), and mouse can be used to efficiently understand the organization, regulation, and function of much of the human genome. Functional genomics research is a key link between human genomic sequencing, that provides a complete parts list for the human genome, and the development of information (a high-tech owner's manual) that is useful in understanding normal human development and disease processes. The mouse continues to be a major focus of our efforts and is an integral part of our functional genomics research program. This effort is greatly enhanced by the completion of the Center for Comparative and Functional Genomics at Oak Ridge National Laboratory in FY 2003 that will serve as a national focal point for high throughput genetic studies using mice. 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 high-throughput strategies for using model organisms such as the mouse, *Fugu*, and *Ciona* to understand the function of human genes increases in FY 2004.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

In FY 2003 $4,107,000 was transferred for genomic analysis of potential biothreat agents to the Department of Homeland Security.

	FY 2002	FY 2003	FY 2004
SBIR/STTR	**0**	**4,771**	**5,267**

In FY 2002 $4,458,000 and $256,000 were transferred to the SBIR and STTR programs, respectively. FY 2003 and FY 2004 amounts are estimated requirements for continuation of these programs.

	FY 2002	FY 2003	FY 2004
Total, Life Sciences	**186,384**	**190,878**	**201,408**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Structural Biology	
▪ Maintain structural biology research at near FY 2003 levels.	-38
Molecular and Cellular Biology	
▪ Decrease in Microbial Genomics research decreases capability to obtain and compare microbial DNA sequences	-1,149
▪ Maintains carbon sequestration research at near FY 2003 level...............................	-11
▪ Increase for Genomes to Life research with focus on characterization of molecular machines and on development of broad capabilities for large scale protein production and diverse imaging approaches. Increase in high throughput DNA sequencing of individual microbes and microbial communities. Funding provided for Homeland Security in FY 2003 is budgeted by the Department of Homeland Security in FY 2004.	+24,492
▪ BER Human Frontier Science Program completed ………………………………..	-1,000
▪ Maintains Low Dose Radiation Research at near FY 2003 levels.............................	-27
Total, Molecular and Cellular Biology	+22,305
Human Genome	
▪ Decrease in JGI and Tools for Sequencing and Sequencing Analysis reflects completion of human DNA sequencing for the International Human Genome Program and support for DNA sequencing needs of the Genomes to Life program within that program. JGI DNA sequencing capacity is shifted to address the needs of the broader scientific community.	-11,375
▪ Decrease in ethical, legal, and societal issues program (approximately 3% of human genome funding) due to overall decrease in human genome funding	-858
Total, Human Genome	-12,233
SBIR/STTR	
Increase in SBIR/STTR due to increase in research funding for the Life Sciences program and increased STTR allocation...	+496
Total Funding Change, Life Sciences	+10,530

Climate Change Research

Mission Supporting Goals and Measures

The goal of the Climate Change Research subprogram is to deliver relevant scientific knowledge that will enable scientifically-based predictions and assessments of the potential effects of greenhouse gas and aerosol 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). It also contributes to the Administration's Climate Change Research Initiative (CCRI).

In FY 2003, the Administration launched a new CCRI. The CCRI is a set of cross-agency programs in areas of climate change research of high priority and where substantial progress is anticipated over the next three to five years. The specific focus areas of the research are climate forcing (atmospheric concentrations of greenhouse gases and aerosols), climate feedbacks and sensitivity, climate modeling, including enabling research, regional impacts of climate change, including environment-society interactions, and climate observations. In FY 2003 funding allows DOE to participate in one of the specific research areas: climate forcing, which includes modeling carbon sources and sinks, especially those in North America. In FY 2004 ($25,335,000) BER will continue to support research to quantify the magnitude and location of the North American carbon sink, a high priority need in the interagency Carbon Cycle Science Plan and expand its CCRI research to include climate modeling, Atmospheric Radiation Measurement, and Integrated Assessment activities.

The National Institute for Global Environmental Change (NIGEC) is integrated throughout the subprogram (FY 2004 Request is $8,749,000). NIGEC regional centers are located at the University of California, Davis (Western Region), the University of Nebraska, Lincoln (Great Plains Region), Indiana University, Bloomington (Northeast Region), Tulane University, New Orleans (Southcentral Region), and the University of Alabama, Tuscaloosa (Southeastern Region). The national NIGEC center is located at the University of California, Davis.

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 their interactions with 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 element 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.

Within Ecological Processes, new research will be initiated to develop a mechanistic understanding of how complex ecosystems respond to environmental changes, including the causal mechanisms and pathways underlying observed responses. The focus will be on documenting and understanding the causal mechanisms and pathways of biological and ecological responses ranging from the proteome of individual species to the whole ecosystem. The initial focus will be to understand the responses of a model terrestrial ecosystem containing simplified but hierarchical communities (higher plants, consumers of plant production, and soil microorganisms) to changes in a key environmental factor such as temperature that is known to affect ecosystem functioning (e.g., carbon and nutrient cycling). Advanced biologically based computational algorithms and ecosystem models will be developed to establish whether and how changes in the proteome, in either single species or whole systems, can explain the responses and behavior of complex ecosystems.

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 climate change data and make it available for use by the broader climate change research community.

The Climate Change Research subprogram provides fundamental knowledge building to long-term outcomes that underpin the Program Strategic Performance Goals and the Office of Science's Strategic Objectives. Periodic retrospective analysis will be employed to evaluate the accumulation of knowledge and validate specific outcomes. This program was examined as part of a BERAC review of the entire BER program in FY 2001. The next scheduled comprehensive review of the Climate Change Research subprogram by BERAC will be in FY 2005. The following are recent scientific accomplishments that highlight program progress.

- *Model results provide further evidence that 20th century warming is caused by greenhouse gas.* Scientists from BER's Climate Change Prediction Program have provided further evidence that the observed climate warming in the twentieth century is due to human induced forcing of the climate system. The scientists compared results from two ensembles of twentieth century climate simulations with observational temperature records. The climate forcing conditions in the climate model used to produce one ensemble included all known sources of natural variability, including temporal changes in solar output and the cooling effects of volcanic dust. A model used to produce a second series of runs also included anthropogenic effects on the atmosphere, i.e., increased greenhouse gas concentrations and aerosols. The ensemble from the model that included anthropogenic forcings closely matched the observed record and was a statistically significant 0.3 C warmer at the end of the century than the runs from the model that contained only natural variability.

- *Anomalous Absorption of Solar Radiation Question is Resolved.* BER's Atmospheric Radiation Measurement (ARM) program resolved a long-standing scientific question concerning the transfer of solar radiation through the atmosphere. A considerable body of scientific literature indicates that measurements of the absorbed solar energy in cloudy atmospheres exceed theoretical calculations. A group of papers published in 1995 claimed that the ratio of measured to calculated absorption was as large as 1.4 or 1.5. If the ratio were this large, it would require a substantive reevaluation of our understanding of atmospheric radiation physics because such a large increase could not be explained by any reasonable extrapolation of currently understood physics. To test this, the ARM Program conducted field campaigns utilizing ground and aircraft borne instruments coordinated with satellite measurements. Results show that measured solar absorption in a cloudy atmosphere is within a few to 15% of absorption computed from state-of-the-art radiative transfer models. These results indicate that anomalous absorption occurs only at the level of 15% or less and can be explained by conventional atmospheric physics.

- *ARM Develops New Parameterization for Ice Crystals in Cirrus Clouds.* Using detailed information from the Atmospheric Radiation Measurement (ARM) site in the Southern Great Plains, ARM researchers have improved how the scattering of sunlight by ice crystals in cirrus clouds is represented in models. The new parameterization was incorporated into a model that simulates the atmosphere over the ARM site. Actual measurements from the ARM sites were used to assess the realism of the model simulations, and the model version that used the new treatment showed excellent agreement. Comparison between the new model and a numerical weather forecasting model with observations also shows that the new model is more accurate. The use of the new cloud parameterization improved the computed rates at which the atmosphere cools radiatively by as much as 20 percent when averaged over a season. Larger improvements occurred for specific days.
- *New Understanding of Air Pollution Phenomena Leads to Advances in Air Pollution Control Strategies.* Through coordinated field research, laboratory measurements, and modeling studies in a variety of areas around the U.S. such as Nashville, Phoenix, Salt Lake City, and Houston, the Atmospheric Sciences Program (ASP) provided new insights into the diversity of factors that affect air quality and showed that a "one-approach-fits-all" strategy for air quality management does not work. The research demonstrated that reducing industrial emissions of volatile organic compounds in Houston could reduce ozone concentrations there, but this strategy would be less effective in the southeastern U.S., where reactive volatile organic compounds tend to be dominated by natural emissions from vegetation. In Phoenix, on the other hand, emissions of hydrocarbons from vegetation and industrial sources are minimal, so the focus should be on reducing emissions from vehicles. Since most of the emissions associated with energy production and use are to the atmosphere, understanding how such emissions are transported, transformed, and removed from the atmosphere is essential for understanding their environmental consequences, in terms of air quality, climate change, and health effects. Research results from the Atmospheric Science Program are provided well beyond the research community, both to industry and to state authorities for use in assessing and developing air pollution control strategies.
- *New Method Developed for Measuring Total Soil Carbon.* Laser-induced breakdown spectroscopy (LIBS) is a new method for measuring soil carbon content that significantly advances research on the cycling and sequestration of carbon in soil. LIBS was developed by researchers at the Los Alamos National Laboratory and further tested by ORNL and USDA/ARS Laboratories The method directly measures soil carbon by "shooting" a small laser beam into the soil matrix in the field, and spectra of soil organic matter broken down by the laser are resolved to estimate the quantity of carbon present in the soil matrix. LIBS analyzes the sample in less than one minute, and results exhibit excellent precision and accuracy when correlated with conventional dry-combustion techniques for measuring soil carbon content. The field-portable LIBS device has been tested with a number of natural soil configurations and morphologies, and has been found to perform faster and more efficiently than conventional approaches. LIBS offers the potential of revolutionizing soil carbon measurement, where fast determinations are useful for many practical applications of soil carbon inventory, management and sequestration. Research is continuing jointly with the USDA to determine effects of other soil properties such as texture, mineralogy and moisture content on performance of LIBS.

- *Iron Fertilization Makes Ocean Bloom.* The Southern Ocean Fertilization Experiment (SOFeX) jointly funded by BER and the National Science Foundation demonstrated that carbon fixation by ocean phytoplankton in the Southern Ocean south of New Zealand is iron limited and can be enhanced by fertilizing ocean surface water with iron. Data from SOFeX demonstrate that iron fertilization may offer a potential approach for enhancing carbon sequestration in the ocean by increasing the rate of carbon fixation by ocean phytoplankton. The SOFeX data will be used to constrain estimates of the amount of carbon in particles, including phytoplankton that is exported downward into the deep ocean where it is isolated from the atmosphere, a prerequisite for ocean carbon sequestration. In January-February 2002, over 100 scientists and 3 research vessels fertilized the surface ocean water in two 15 square kilometer study areas with dissolved iron and inert chemical tracers. The latter was to tag the ocean water in the two areas fertilized so as to be able to distinguish the areas and volumes of water fertilized from those not fertilized. Addition of the iron produced a bright green phytoplankton bloom in the two areas fertilized that could be seen from space by ocean color satellites, evidence that the addition of iron enhances the growth and carbon fixation by phytoplankton in the Southern Ocean.

- *First Field Test of Multiple Ecological Models with Three Years of Independent Data.* BER's Program on Ecosystem Research recently completed a rigorous evaluation and testing of nine terrestrial ecosystem models in collaboration with NASA, NSF, and the Canadian government by comparing model simulations with independent field data. It was discovered that more complex models tended to provide more accurate predictions of short-term (i.e., daily) water and carbon dioxide exchange rates, but that model complexity was apparently unrelated to accuracy of monthly and annual predictions. This type of model evaluation is essential to understanding uncertainties and limitations of ecological models used to predict and assess effects of global and regional environmental changes on the structure and functioning of terrestrial ecosystems. Several model improvements have already resulted from this work.

  The models (which represented a wide range of model complexity) were compared to three years of field data collected on ecosystem water use, net primary production, gross primary production, net ecosystem production, and soil carbon dioxide release in a boreal spruce forest. This was the most extensive test of forest ecosystem models using independent field data conducted to date, and represented forest responses to natural climatic variability in interior Canada.

Subprogram Goals

Determine the response of the Earth system to different levels of greenhouse gases in the atmosphere.

Performance Indicator

Climate model resolution.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
(Climate and Hydrology)	(Climate and Hydrology)	(Climate and Hydrology)
A new coupled model was released in May 2002, with an average resolution of 280 km in the atmosphere and 60 km in the ocean. The previous version had a resolution of 280 km and 200 km, respectively. An 800-year equilibrium climate simulation was executed at the National Energy Research Supercomputer Center. [Goal Met] Addition of new cloud submodel for cirrus clouds improved climate model computed rates at which atmosphere cools radiatively by 20%. [Goal Met]	Increase the realism of the coupled modeling system through both increases in spatial resolution and improvements in the physical parameterizations. More objective and systematic methods for evaluating model performance will be implemented and applied to the model components (atmosphere, ocean, land and sea ice) as well as to the coupled modeling system. Model productivity will be increased by completing a larger number of scenarios of climate change forcing and making the results available to researchers in the broader community. This will be made possible by a significant effort in software engineering and algorithm development so that the model is able to exploit new computing technology rapidly and efficiently.	By the end of 2004, incorporate climate data rapidly into climate models to allow testing of the performance of submodels (e.g., cloud resolving module) and model parameters by comparing model simulations with real world data from the ARM sites.
(Atmospheric Chemistry & Carbon Cycle)	(Atmospheric Chemistry & Carbon Cycle)	(Atmospheric Chemistry & Carbon Cycle)
Coordinated field and laboratory measurements and modeling experiments in diverse regions demonstrate that regional air quality management strategies must be designed for the specific regional environment, e.g., one size does not fit all. [Goal Met]	Evaluate preliminary findings from field measurement campaigns in both atmospheric chemistry and environmental meteorology and the extent to which scientific results are incorporated into models to predict and assess air quality. Produce quality micrometeorological data, net carbon dioxide exchange data, and biometric data from 20 of 45 active AmeriFlux sites, and synthesize results from these sites.	The program will incorporate respiration functions into biophysical carbon cycle models for terrestrial ecosystems calculating carbon exchange for three woody ecosystems. Independent data will be used to evaluate model improvement.
Data from the Southern Ocean Iron Fertilization Experiment demonstrated that iron added to the ocean may enhance carbon sequestration by ocean phytoplankton. [Goal Met]	Analyze and publish results from the Southern Ocean Iron Fertilization Experiment (SOFeX) that 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 ocean's surface.	Data from the Southern Ocean Iron Fertilization Experiment (SOFEX) will be incorporated into coupled biogeochemical models to evaluate the effectiveness of ocean fertilization as a carbon sequestration strategy. New field studies will be initiated to examine the fate of carbon exported from the surface ocean to intermediate depths (100m-1000m) and the carbon sequestration potential.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
New method developed for measuring soil carbon will provide faster and more accurate measurement of soil carbon, data that are needed for carbon cycle modeling in diverse ecosystems. [Goal Met]	Apply an ecosystem framework to estimate annual rates of actual carbon gain by vegetation and soil. Enhanced sequestration will be estimated relative to baseline carbon quantities established for the range of ecosystems investigated by the CSiTE Consortium.	CSiTE will estimate the biophysical potential of terrestrial carbon sequestration for one specific region of the U.S. New field data, analysis of full carbon accounting, and improved carbon cycle models will demonstrate how existing carbon stocks of terrestrial vegetation and soil could be increased.
(Ecological Processes)	(Ecological Processes)	(Ecological Processes)
Nine ecological models tested with three years of independent field data provide the framework for understanding model limits for predicting ecosystem responses to environmental change. [Goal Met]	Complete 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.	Establish a model terrestrial ecosystem in a controlled and controllable environment that contains simplified but hierarchical communities (higher plants, consumers of plant production, and soil microorganisms) and begin the characterization of the proteome of the major species.
(Human Interactions)	(Human Interactions)	(Human Interactions)
Integrated assessments provided a basis for quantifying the potential significance of enhancing carbon sequestration in terrestrial ecosystems, ocean, and/or geologic formations with the goal of reducing CO_2 concentrations. Sequestration strategies that have limited lifetimes, either because of constraints on the amount of carbon sequestered or on the expected residence time before re-release, can be compared economically with other strategies that may be more expensive, such as premature replacement of capital stocks. [Goal Met] 15 undergraduate summer fellowships were awarded. In addition, 27 graduate students were supported, 7 first year, 6 second year, 7 third year, and 7 fourth year students. All granduate and undergraduate students worked with DOE-funded scientists and/or at DOE facilities. [Goal Met]	Integrate a new land and ocean carbon sub-model in one of the two large integrated assessment models. 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. The other integrated assessment model will 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.	Performance will be measured by the sustaining the number, quality, and diversity of students enrolled in the program and by end-of-summer evaluations by students and their mentors.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
	Performance will be measured by the number, quality, and diversity of students enrolled in the program and by end-of-summer evaluations by students and their mentors.	

Manage all BER facility operations to the highest standards of overall performance, using merit evaluation with independent peer review.

Performance Indicator

Average operational downtime of BER facilities will not exceed 10% of total time scheduled.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
(Climate and Hydrology)	(Climate and Hydrology)	(Climate and Hydrology)
ARM instruments averaged over a 95% up time in 2002 and successfully completed 7 IOP's. [Goal Met]	Achieve a downtime of less than five percent for the principal ARM instruments and successfully conduct five IOPs across the three ARM sites.	Achieve a downtime of less than five percent for the principal ARM instruments and successfully conduct five IOPs across the three ARM sites.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Climate and Hydrology	70,353	74,669	74,559	-110	-0.1%
Atmospheric Chemistry and Carbon Cycle	34,735	37,764	37,707	-57	-0.2%
Ecological Processes	12,817	13,888	18,726	+4,838	+34.8%
Human Interaction	7,942	8,084	8,071	-13	-0.2%
SBIR/STTR	0	3,554	3,896	+342	+9.6%
Total, Climate Change Research	125,847	137,959	142,959	+5,000	+3.6%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Climate and Hydrology	**70,353**	**74,669**	**74,559**
■ **Climate Modeling**..	**26,999**	**27,181**	**27,138**

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 provide climate modelers access to 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 climate processes. In FY 2004, 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 emphasize 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.

For CCRI the research will provide ensemble projections of multi-century climate change using the Community Climate System Model through the Climate Change and Assessment Working Group. Additionally, the program will provide the infrastructure for major model evaluation and model improvement research through the coordination of model intercomparisons and the maintenance of model testbeds for parameterization testing. In FY 2004 ($15,347,000) climate model experiments will provide scenarios, such as carbon dioxide (CO_2) stabilization scenarios.

In FY 2004 BER's SciDAC program ($7,776,000) is focused on improving the models used for climate simulation and prediction. A major effort is dedicated to providing a robust and extensible software engineering framework for the Community Climate System Model, a code used by hundreds of researchers on many different high-end computing platforms. Additional research will

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

provide the prototype climate model of the future that will explore approaches to climate simulation and prediction for the next ten years.

The research activities in this subprogram are carried out at National Laboratories, universities, and at private institutions and are selected through competitive and peer-reviewed processes.

In FY 2004, NIGEC will continue to support research to evaluate the reliability of using isotopic signatures of trace gases in ice cores for interpreting past climate variation and change and the relationship between greenhouse gas concentrations and climate change (FY 2004 Request is $2,187,000).

▪ **Atmospheric Radiation Measurement (ARM) Research**	**13,310**	**13,310**	**13,247**

In FY 2004, the principal goal of the ARM scientific enterprise continues to be the development of 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. In addition, a model parameterization testbed initiated in FY 2003 will be continued to enable the testing and improvement of submodels by rapidly incorporating data from the ARM sites into the models to enable diagnostic tests and intercomparisons of model simulations with real world data.

▪ **Atmospheric Radiation Measurement (ARM) Infrastructure** ..	**27,306**	**31,441**	**31,441**

In FY 2004, the Atmospheric Radiation Measurement (ARM) infrastructure program will continue to develop, support, and maintain 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, pyrgeometers, 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 2002	FY 2003	FY 2004

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 (IOPs). 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 UAV program will conduct a major field campaign in conjunction with the ARM program to measure the effect of cirrus clouds on the absorption and scattering of downwelling radiation over the Western Tropical Pacific ARM-CART site.

The CCRI ARM program will deploy a mobile climate observatory to provide new atmospheric measurements needed to fill data gaps and will develop the corresponding data products needed for evaluating and modeling the effects of atmospheric processes and properties on the radiation balance and for developing and evaluating the models. In FY 2004 ($4,100,000) a mobile Cloud and Radiation Testbed (CART) facility will be deployed in a selected data poor region (e.g., tropics) or a region that represents a location of opportunity for measuring the effects of atmospheric conditions on the radiation balance that are currently poorly understood (e.g., direct and indirect effects of aerosols). The mobile site will be instrumented for cloud and radiation measurements. The primary siting criterion is to provide those measurements needed to address specific modeling needs that presently cannot be addressed by the permanent ARM sites. Activities will be coordinated with other U.S. agencies and international partners, such as Australia, Japan, China, and European countries. Data products will be developed through collaborations with model developers. In FY 2004 the criteria for data products for evaluating precipitation processes will be established.

The research activities in this subprogram are carried out at National Laboratories, universities, and at private institutions and are selected through competitive and peer-reviewed processes.

	FY 2002	FY 2003	FY 2004
■ **Atmospheric Radiation Measurement (ARM)/Unmanned Aerial Vehicles (UAV)**	**2,738**	**2,737**	**2,733**

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 balance.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Atmospheric Chemistry and Carbon Cycle	**34,735**	**37,764**	**37,707**
▪ **Atmospheric Science**	**13,161**	**12,571**	**12,551**

The Atmospheric Science project will continue to 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 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 2004 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 climate 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 2004 the Atmospheric Sciences subprogram will, in general, focus on the evaluation of findings from field measurement campaigns in both atmospheric chemistry and environmental meteorology.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

In FY 2004, 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 2004 Request is $2,187,000).

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▪ **Terrestrial Carbon Processes and Ocean Sciences**	**13,056**	**16,636**	**16,613**

In FY 2004, BER will continue supporting the AmeriFlux program, a network of approximately 25 research sites that measure 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 5 to 10 AmeriFlux sites.

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

The continuing 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).

In FY 2004 (FY 2003 $2,920,000; FY 2004 $2,916,000) BER CCRI activities on the carbon cycle will continue to explore the movement of carbon starting from natural and human-induced emissions to the atmosphere to ultimate sinks in the terrestrial biosphere and the oceans. The AmeriFlux sites supported by BER are essential to quantifying the net exchange of carbon between the atmosphere and major terrestrial ecosystems in North America. Hence, they are essential to documenting the magnitude and variation in the North American carbon sink and how it is affected by variation and changes in environmental factors such as climate. BER will continue measurements and process studies at the network of AmeriFlux sites across North America. This information, along with data from extensive measurements around the sites, will provide a sound scientific basis for extrapolating carbon flux measurements at AmeriFlux sites to landscape and regional scales. Hence, it will improve estimates of the magnitude of the North American carbon sink and identify the regions and ecosystem types that account for the sink. In FY 2004 the research will deliver an intercomparison of estimates of the net annual exchange of CO_2 between terrestrial ecosystems and the atmosphere for a region of the U.S. with independent estimates using atmospheric sampling and inverse modeling.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
■ **Carbon Sequestration Research**	**8,518**	**8,557**	**8,543**

In FY 2004, 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, Carbon Sequestration in Terrestrial Ecosystems (CSiTE) ($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 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 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.

In FY 2004, university scientists will continue the analyses of research results on the effects of iron fertilization on plankton communities in the Southern Ocean. 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.

Ecological Processes	**12,817**	**13,888**	**18,726**

In FY 2004, new ecological research will be initiated to develop a more mechanistic understanding of the scales of response of complex ecosystems to environmental changes, including identifying the underlying causal mechanisms and pathways and how they are linked, ranging from the proteomes of individual species to the whole ecosystem. The focus initially will be on understanding the linkages of scales in model terrestrial ecosystems containing simplified but hierarchical communities (higher plants, consumers of plant production, and soil microorganisms). A key environmental factor such as temperature that is known to affect ecosystem functioning (e.g., carbon and nutrient cycling) will be experimentally manipulated and proteomic responses of individual species and the whole ecosystem will be measured. Advanced biologically based computational algorithms and ecosystem models will be

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

developed to establish whether and how proteomic changes (in either single species or whole systems) explain the responses and behavior of complex ecosystems. Tools and principles developed from this research should have broad generality and eventual application to problems in carbon sequestration, ecological risk assessment, environmental restoration and cleanup, and early detection of ecological responses to climate change and other environmental factors.

BER will continue four Free-Air Carbon Dioxide Enrichment (FACE) experiments at Duke University (North Carolina), Rhinelander (Wisconsin), Oak Ridge (Tennessee), and Mercury (Nevada) on the Nevada Test Site to improve understanding of the direct effects of elevated carbon dioxide and other atmospheric changes on the structure and functioning of various terrestrial ecosystems. Emphasis will be on understanding the cause 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.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

In FY 2004, 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 2004 Request is $2,625,000).

Human Interactions	**7,942**	**8,084**	**8,071**
▪ **Human Interactions**	**7,942**	**8,084**	**8,071**

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 goal is to improve the integrated assessment models to include several greenhouse gases, 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 improvement 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.

In FY 2004, 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 2004 Request is $1,750,000).

The Integrated Assessment research program will fund research to develop internally consistent sets of scenarios that can be used for national-scale decision-making. The scenarios will be evaluated in selected integrated assessment models, also funded by the Integrated Assessment program. In FY 2004 ($2,972,000) the Integrated Assessment program will produce at least four scenarios to provide alternatives to the scenarios that were published by the Intergovernmental Panel on Climate Change. These scenarios will include forecasts of such items as economic productivity, population, and energy use by global region. They will serve as input to the Integrated Assessment Models and will be used as input to decision support analysis in the new CCRI.

The Information and Integration element stores, evaluates, and quality-assures a broad range of global environmental change data, and disseminates those data 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.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		
SBIR/STTR	**0**	**3,554**	**3,896**
In FY 2002 $3,152,000 and $188,000 were transferred to the SBIR and STTR programs, respectively. FY 2003 and FY 2004 amounts are the estimated requirements for continuation of these programs.			
Total, Climate Change Research	**125,847**	**137,959**	**142,959**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Climate and Hydrology	
▪ Held at near FY 2003 level. Change is due to increase in STTR allocation	-110
Atmospheric Chemistry and Hydrology	
▪ Held at near FY 2003 level. Change is due to increase in STTR allocation.	-57
Ecological Processes	
▪ The increase will support new research on scaling from the molecular level in individual organisms up to the aggregate ecosystem scale. The focus is on research to understand and model how complex ecosystems respond to the environment, including the causal mechanisms and pathways underlying observed responses, ranging from the proteome of individual species to the whole system. Tools and principles developed from this research will have eventual application to problems in carbon sequestration, ecological risk assessment, environmental restoration and cleanup, and early detection of ecological responses to climate change and other environmental perturbations caused by energy production and use.	+4,860
▪ Traditional Ecological Processes research held at near FY 2003 levels.	-22
Total, Ecological Processes	+4,838
Human Interactions	
▪ Held at near FY 2003. Decrease is due to increase in STTR allocation	-13

	FY 2004 vs. FY 2003 ($000)
SBIR/STTR	
■ Increase in SBIR/STTR due to increase in STTR allocation and increase in research funding for the Climate Change Research program.	+342
Total Funding Change, Climate Change Research	+5,000

Environmental Remediation

Mission Supporting Goals and Measures

The mission of the Environmental Remediation subprogram is to deliver the scientific knowledge, technology and enabling discoveries in biological and environmental research to reduce the costs, risks, and schedules associated with the cleanup of the DOE nuclear weapons complex; to extend the frontiers of biological and chemical methods for remediation; to discover the fundamental mechanisms of contaminant transport in the environment; to develop cutting edge molecular tools for investigating environmental processes; and to develop an understanding of the ecological impacts of remediation activities. In addition much of the work performed for the cleanup program will provide fundamental knowledge that applies to a broad range of remediation problems, as well to the development advanced nuclear waste management approaches and predicting and avoiding environmental hazards for future nuclear energy options.

Research priorities include bioremediation, contaminant fate and transport, nuclear waste chemistry and advanced treatment options, and the operation of the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) and the Savannah River Ecology Laboratory (SREL).

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 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 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.

The Clean Up Research and Environmental Management Science Programs (EMSP) focus on a variety of solutions for the DOE weapons complex cleanup effort. Three primary elements include: contaminant fate and transport in the subsurface, nuclear waste chemistry and advanced treatment option, and novel characterization and sensor tools. In addition, studies on bioremediation of organic contaminants are conducted in EMSP, complementing the NABIR program, which focuses on metals and radionuclides. This program works closely with related programs in the Basic Energy Sciences program and with related programs of other agencies. The SREL is managed through a cooperative agreement with the University of Georgia and performs ecological research aimed at ensuring that environmental cleanup operations do not disturb the biodiversity at the restored environment.

Within Facility Operations, support of the EMSL national user facility operations is focused on providing advanced molecular tools to the scientific community in such areas as environmental remediation sciences, biology and genomics, and atmospheric science. In FY 2004, unique EMSL facilities, such as the newly upgraded Molecular Science Computing Facility, the new (in FY 2003) 900 MHz NMR, and the High-Field Mass Spectrometry Facility will expand both their scientific scope and their user base.

The Environmental Remediation subprogram provides fundamental knowledge building to long-term outcomes that underpin the Program Strategic Performance Goals and the Office of Science's Strategic Objectives. Periodic retrospective analysis will be employed to evaluate the accumulation of knowledge and validate specific outcomes. This program was reviewed as part of a BERAC review of the entire BER program in FY 2001. The next scheduled comprehensive review of the Environmental Remediation Sciences subprogram by BERAC will be in FY 2003. The following are recent scientific accomplishments that highlight program progress.

- *EMSP Project Results in Commercialized D&D Tool for use at DOE Sites.* An Environmental Management Science Program project "Atmospheric-Pressure Plasma Cleaning of Contaminated Surfaces" has just been licensed and is being commercialized by APJet Inc. The project, collaboration between Los Alamos National Laboratory (LANL) and University of California, Los Angeles (UCLA), began at LANL out of basic research on cold plasmas at atmospheric pressures. The commercialized product will be used for removing contaminants from surfaces during D&D operations at DOE sites.
- *Theoretical Work Results in Advanced Separations Agents for Nuclear Wastes.* Using theoretical methods and the computing capabilities at EMSL, a new class of designer molecules that are highly organized for selective complexation with transuranic elements has been designed. In this EMSP project, preliminary experimental results suggest that these new molecules, called bicyclic diamides exhibit distribution coefficients for certain transuranics that are 10 *million times* larger than conventional diamides used in the current Purex process for separating transuranics from high-level nuclear waste media.
- *Some Microorganisms can "sniff out," produce flagella, and swim toward metal oxides.* Natural and Accelerated Bioremediation Research Program (NABIR) funded studies show that microorganisms that use insoluble metal oxides to drive energy metabolism play important roles in the bioremediation of metal and organic contaminants in groundwater. Although iron oxides are often present in subsurface environments, microbes must find and access these insoluble substrates to live. A surprising finding in the genetic code of a common bacterium, *Geobacter*, led to the discovery of an unusual strategy for survival in subsurface environments. The genome of *Geobacter metallireducens* was sequenced through the Microbial Genome Program at the Joint Genome Institute. The sequence data revealed that *Geobacter,* previously thought to be immobile, can produce flagella that allow it to swim toward metal oxides. Thus, *Geobacter* appears to have a built-in sensor that allows it to "sniff out" and find metals oxides. *Geobacter* is of great interest to the DOE because it can precipitate uranium, and therefore offers a potentially efficient and economic solution to removing uranium from contaminated groundwater through *in situ* immobilization.

- *Innovative Sensors for Field Detection of Environmental Contaminants Developed*. A novel handheld sensor for detecting uranium in the environment has been developed in the NABIR program using a monoclonal antibody with specificity for uranium and an instrument developed by Sapidyne Instruments, Inc. The prototype "immunosensor" has been shown to detect soluble uranium oxide at extremely low concentrations (2.5 to 24 ppb). These portable sensors yield reliable data in real time (< 1 hour), are field ready (simple, durable, accurate) and inexpensive (<$5,000 per instrument). Work is underway to develop new monoclonal antibodies for chromium and mercury for detection in the environment.
- *EMSL Users and Scientists Conduct Computational Science Studies with New Linux-Based Supercomputer* - A new 8.3 teraflop, Linux-based supercomputer at the EMSL has been made available for grand challenge teams of scientists to apply computational science to study complex chemical problems that form the basis for new discoveries in areas such as subsurface transport, atmospheric chemistry, materials design, life sciences and systems biology, and combustion. The new massively parallel system is more than 30 times faster, has 50 times more disk space and holds 10 times as much memory as EMSL's original supercomputer.
- *900 MHz Nuclear Magnetic Resonance (NMR) Spectrometer at the EMSL Provides Improved Resolution of Protein Structures* - EMSL users and scientists are obtaining high resolution data on the atomic structures of large and unstable proteins using EMSL's 900 MHz wide-bore NMR. Because certain types of proteins are difficult to crystallize, and therefore not amenable to structure determination using DOE's light sources, the EMSL's 900 MHz NMR is proving to be the only alternative to resolving the structure of these "difficult" proteins. In addition, because the proteins are examined in a solution state, the resolved structures may be more "realistic" than crystallized samples.

Subprogram Goals

Develop and demonstrate novel solutions to DOE's most challenging problems, including 1) in situ treatment of contaminant plumes such as bioremediation and environmental reactive barriers, 2) new treatment options for complex wastes, 3) novel disposal options for complex wastes (e.g. alternative to borosilicate glass); cost-effective contaminant plume characterization and monitoring techniques for long-term stewardship of sites, 5) improved predictive capabilities for contaminant fate and transport, and 6) basis for accurate assessment of risk factors.

Performance Indicator

Advanced environmental cleanup approaches delivered.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
(NABIR & Bioremediation Research)	(NABIR & Bioremediation Research)	(NABIR & Bioremediation Research)
Using data from genomic sequences of key bioremediation microorganisms such as *Geobacter, Deinococcus* and *Shewanella*, a molecular level understanding of the detection and transformation of metals and radionuclides is being achieved. Physiological studies of microorganisms have shown that common soil microorganisms produce organic compounds that interact with radionuclides, including plutonium. Research at Uranium Mill Tailings Remedial Action sites has demonstrated the potential to use biostimulation to reduce and immobilize uranium in the subsurface. In partnership with EM-50, two new projects have been initiated at Hanford to study the use biostimulation (addition of nutrients) to remove chromium and technetium from ground water. [Goal Met]	Complete two critical field experiments at the NABIR Field Research Center 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 Demonstrate, in partnership with the Office of Environmental Management, the reliability of new biologically based technologies for monitoring radionuclides 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 function of microbial communities in contaminated environments.	By the end of FY 2004, demonstrate whether certain nutrient additions stimulate subsurface microorganisms to immobilize uranium, thereby reducing its concentration and transport in soil water and groundwater. The field experiment 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**.** Successful demonstrate, in partnership with the Office of Environmental Management's Science and Technology program, the reliability of 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.
(Environmental Management Science Program)	(Environmental Management Science Program)	(Environmental Management Science Program)
Performed analysis of program scope and management and developed a strategic plan for incorporating EMSP into Environmental Remediation Sciences in preparation for the FY 2003 transfer from the Office of Environmental Management as requested in the President's FY 2003 budget. [Goal Met]	Begin integration of EMSP into Environmental Remediation Sciences, including coordination with ongoing NABIR research. Develop two new activities with EMSP: (1) develop plan with SRS and EMSP investigators for a Bioremediation Project at the Savannah River Site. Assess the needs for user facilities and capabilities for	Complete integration of EMSP into Environmental Remediation Sciences, including coordination with ongoing NABIR research. Initiate R&D projects to support SRS Bioremediation Project. Start development of user facility enhancements.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
	environmental research, including the synchrotron light sources, neutron scattering facilities, and computation centers.	
(Savannah River Ecology Laboratory) Performed analysis of program scope and management and developed strategic plan for incorporating SREL into Environmental Remediation Sciences in preparation for the FY 2003 transfer from the Office of Environmental Management as requested in the President's FY 2003 budget. [Goal Met]	(Savannah River Ecology Laboratory) Develop a plan, working with the University of Georgia and the Savannah River Site to increase the scope of ecology research and education programs at SREL.	(Savannah River Ecology Laboratory) Initiate new peer reviewed ecology research programs at the Savannah River site and new education programs at SREL.

Manage all BER facility operations to the highest standards of overall performance, using merit evaluation with independent peer review.

Performance Indicator

Average operational downtime of BER facilities will not exceed 10% of total time scheduled.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
(Environmental Molecular Sciences Laboratory) First phase of new high performance computer delivered and meeting performance benchmarks, achieving 1 Tflop in FY 2002. The number of FY 2002 users increased by approximately 10% over FY 2001. Unscheduled downtimes on the major instrument / computer systems did not exceed 10%. Successful receipt and testing of the 900 MHz NMR was completed. [Goal Met]	(Environmental Molecular Sciences Laboratory) (1) Initiate operation of a new high performance computer at the EMSL reaching 9 Tflop performance and (2) unscheduled operational downtime on EMSL instrumentation and computational resources will not exceed 10 percent.	(Environmental Molecular Sciences Laboratory) (1) Full operation at 9 Tflop of the new supercomputer at the EMSL and (2) unscheduled operational downtime on EMSL instrumentation and computational resources not to exceed 10 percent.

Funding Schedule

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Bioremediation Research	29,320	30,700	29,867	-833	-2.7%
Clean Up Research	44,915	38,190	39,470	+1,280	+3.4%
Facility Operations	37,614	37,948	37,138	-810	-2.1%
SBIR/STTR	0	2,692	2,845	+153	+5.7%
Total, Environmental Remediation	111,849	109,530	109,320	-210	-0.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Bioremediation Research	**29,320**	**30,700**	**29,867**
▪ **NABIR and Bioremediation Research**	**23,365**	**24,720**	**24,097**

In FY 2004, NABIR will continue to 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 2004, science elements in the NABIR program continue fundamental research on 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); and (5) Assessment (measuring and validating the biological and geochemical processes of bioremediation). 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) is located near the Y-12 area at the Oak Ridge Reservation and is the site of field-scale, hypothesis-driven research on the bioremediation of metals and radionuclides. Researchers are characterizing and modeling the subsurface water flow, contaminant transport and biogeochemical processes at the FRC. These experiments will be completed and

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

written up for peer-reviewed publication in FY 2003. In FY 2004, field experiments will continue. These combine both microbiological and chemical treatment of uranium and the common co-contaminant, nitrate.

The NABIR program will continue to take advantage of recently completed genome sequence of important metal and radionuclide-reducing microorganisms to study the regulation and expression of genes that are important to bioremediation. In FY 2004, researchers working on sequenced microorganisms such as *Geobacter sulfurreducens, Desulfovibrio vulgaris*, and *Shewanella onediensis* will use state-of-the-art nucleic acid based microarrays to identify environmental factors affecting genetic regulation of uranium reduction.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

In FY 2004, the activities are reduced to enhance funding for Savannah River Ecology Laboratory.

▪ **General Plant Projects (GPP)**	**4,791**	**4,811**	**4,811**

The General Plant Projects (GPP) funding is continued 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 the requirements for safe and reliable facilities operation. This subprogram includes stewardship 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 process water piping in a 40 year old building used for biological research, refurbishing 20-year old office and laboratory space, and reconfiguring space in several 40+ year old buildings to better accommodate current scientific research projects.

▪ **General Purpose Equipment (GPE)**	**1,164**	**1,169**	**959**

The General Purpose Equipment (GPE) funding will continue to provide general purpose equipment for PNNL and ORISE such as information system computers and networks, and instrumentation that supports multi-purpose research.

Clean Up Research	**44,915**	**38,190**	**39,470**
▪ **Clean Up Research**	**790**	**2,463**	**2,448**

The modest program in clean up research will continue to be managed together with the EMSP program. The focus will continue on biophysical and chemical characterization of environmental contaminants in support of field and laboratory studies of contaminant transport and bioremediation.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▪ **Environmental Management Science Program**	**36,125**	**29,886**	**29,246**

The goal of the Environmental Management Science Program (EMSP), transferred in FY 2003 from Environmental Management 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, provide innovative technical solutions where there are none, and lead to future risk reduction and cost and time savings. It is the intent or the expectation of the EMSP that the basic research projects funded are directed toward specific issues and uncertainties at the DOE sites. EMSP research will focus on contaminant fate and transport in the subsurface, nuclear waste chemistry and advanced treatment options, and novel characterization and sensor tools. In addition, studies on bioremediation of organic contaminants are conducted in EMSP, complementing the NABIR program, which focuses on metals and radionuclides.

EMSP projects will continue to be funded through a competitive peer review process. 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. Research will be funded at universities, national laboratories, and at private research institutes and industries. This research will be conducted in collaboration with the Office of Environmental Management.

In FY 2004, the activities are reduced to enhance funding for the Savannah River Ecology Laboratory.

▪ **Savannah River Ecology Laboratory**...	**8,000**	**5,841**	**7,776**

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 assess the ecological risks of environmental contaminants and remediation activities. 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.

In FY 2004, new ecological research will develop the knowledge needed to understand how site environmental cleanup activities may impact biodiversity at the Savannah River Site and other DOE sites. This will continue a broad educational component at the site including opportunities for K-12, undergraduate, and graduate students, and post doctoral fellows.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Facility Operations: William R. Wiley Environmental Molecular Sciences Laboratory (EMSL)	**37,614**	**37,948**	**37,138**
■ **Operating Expenses**	**33,808**	**35,959**	**35,149**

The EMSL is a scientific user facility located at the Pacific Northwest National Laboratory focused on conducting interdisciplinary, collaborative research in molecular-level environmental science. Operating funds are essential and will continue 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 1200 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 a new Linux-based supercomputer, a 900 MHz nuclear magnetic resonance (NMR) spectrometer that adds to the suite of NMRs in EMSL, 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.

The supercomputer will continue to support two dozen "grand challenge" computational projects at the molecular level and in areas ranging from molecular geochemistry and biogeochemistry, numerical modeling of reactive transport in the subsurface, chemical processing and catalysis, aerosol formation and chemical transformations, climate modeling and simulation, and structural biology.

The research activities using EMSL are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.
BER will maintain and operate EMSL and the structural biology user facilities so that the unscheduled operating downtime will be less than 10%, on average, of total scheduled operating time.

In FY 2004, the activities are reduced to enhance funding for the Savannah River Ecology Laboratory.

	FY 2002	FY 2003	FY 2004
■ **Capital Equipment**	**3,806**	**1,989**	**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 ($2,994,000) in FY 2002 supported the upgrade of user capabilities through the acquisition of additional mass spectrometers and Nuclear Magnetic Resonance (NMR) spectrometers for structural biology research.

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		
SBIR/STTR	**0**	**2,692**	**2,845**

In FY 2002 $2,354,000 and $139,000 were transferred to the SBIR and STTR programs, respectively. FY 2003 and FY 2004 amounts are estimated requirements for continuation of these programs.

	FY 2002	FY 2003	FY 2004
Total, Environmental Remediation	**111,849**	**109,530**	**109,320**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Bioremediation Research	
▪ GPE funding for motor vehicles at PNNL reduced	-210
▪ Funding for NABIR reduced to accommodate increase for Savannah River Ecology Laboratory	-623
Total, Bioremediation Research	-833
Clean Up Research	
▪ Funding for Savannah River Ecology Laboratory restored to FY 2002 level	+1,935
▪ Funding for Clean Up research reduced to accommodate increase for Savannah River Ecology Laboratory	-15
▪ Funding for EMSP reduced to accommodate increase for Savannah River Ecology Laboratory	-640
Total, Clean Up Research	+1,280
Facility Operations: William R. Wiley Environmental Molecular Sciences Laboratory (EMSL)	
▪ Funding for EMSL operations reduced to accommodate increase for Savannah River Ecology Laboratory	-810
SBIR/STTR	
▪ SBIR/STTR increases due to increased STTR allocation and increase in research for Environmental Remediation.	+153
Total Funding Change, Environmental Bioremediation	-210

Medical Applications and Measurement Science

Mission Supporting Goals and Measures

The goal of the Medical Applications and Measurement Science subprogram is to deliver the scientific knowledge and discoveries that will lead to innovative diagnostic and treatment technologies for human health. The research builds on unique DOE capabilities in physics, chemistry, engineering, biology and computational science. 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.

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 for 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 driven by 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 biological and medical imaging (including construction of an artificial retina), 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.

DOE supports cutting edge, high-risk, proof-of-concept research that develops research tools with broad applications in clinical medicine and in biological research. NIH supports cutting edge, disease-specific research that uses those tools, along with many others, to determine fundamental mechanisms of human disease for better diagnosis and treatment. For example, NIH supports clinical imaging research but not research to develop radiotracers or imaging instruments, whereas DOE is the only government agency that supports research to develop imaging instruments and the radiotracers needed to carry out imaging procedures.

The philosophical differences, roles, strengths, and advantages of the DOE versus NIH medical sciences research programs are clear:

- DOE medical sciences research is built on a base of chemistry, physics, engineering, computation, and biology. NIH medical sciences research is built on a complementary base of biology and medicine. DOE research leverages the unique combination of multidisciplinary competencies available at the DOE national laboratories.
- DOE develops research tools for medicine by supporting high-risk research often based on theoretical predictions of success rather than preliminary studies that demonstrate a promise of success. As in other fields of science, high risk research often leads to spectacular advances, e.g., the human genome project and genetics. NIH develops disease-specific applications for these research tools by supporting research that is generally based on substantive preliminary studies that actually demonstrate a promise of success.

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

The Medical Applications and Measurement Science subprogram provides fundamental knowledge building to long-term outcomes that underpin the Program Strategic Performance Goals and the Office of Science's Strategic Objectives. Periodic retrospective analysis will be employed to evaluate the accumulation of knowledge and validate specific outcomes. This program was examined as part of a BERAC review of the entire BER program in FY 2001. The next scheduled comprehensive review of the Medical Applications and Measurement Science subprogram by BERAC will be in FY 2006. The following are recent scientific accomplishments that highlight program progress.

- *First technique to measure Alzheimer's disease onset.* DOE researchers at UCLA have developed an imaging technique that can detect early lesions in the brains of Alzheimer's disease before symptoms begin. The method utilizes a novel radiotracer and highly sensitive PET scanning. Early identification of Alzheimer's lesion offers the possibility of therapeutic intervention before severe brain injury and clinical debilitation occurs.
- *BNCT technology transferred to NIH for clinical trials*. DOE research at the Brookhaven National Laboratories, MIT and Harvard Medical School established the parameters of clinical safety of boron neutron capture therapy in humans. DOE has completed upgrade of the Medical Reactor at MIT; the facility now generates the most advanced neutron beam for clinical studies in the world. Using the fundamental technology developed by DOE, the National Cancer Institute has initiated a BNCT clinical trial in the treatment of brain cancer and melanoma at the MIT medical reactor.
- *Successful transfer of DOE Micro-Pet technology to industry.* DOE investigators at UCLA have successfully developed the Micro-Pet for repeated physiological imaging of small animals without sacrificing the animal. The Micro-Pet is a major advance in the study of animal models of human disease. The technology developed at UCLA has been transferred to Concorde Microsystems, Inc. of Knoxville, TN for marketing and public use.

- *Helping the blind to see.* A collaborative project between USC Doheny Eye Institute, Oak Ridge National Laboratory, Sandia National Laboratory, Argonne National Laboratory, Lawrence Livermore National Laboratory, and Los Alamos National Laboratory is aimed at developing an artificial retina to restore the sight of patients with retinitis pigmentosa and age-related macular degeneration. A milestone was reached in which a prototype design of a high-density sensor was successfully inserted into a canine and tested successfully. Future programmatic goals include improvement in the prototype design of the retinal device and eventually implantation into the eye of a blind person.
- *New, ultra-sensitive detection of prostate cancer protein in the blood*. DOE scientists at ORNL and UC-Berkeley have developed a cancer detecting microchip that works as a sensitive assay for prostate cancer. The device utilizes a micro machine cantilever to detect prostate specific antigen and is twenty times more sensitive than currently used assays. This technology, which has been pioneered at ORNL, can be adapted to measure other clinically important molecules at high levels of sensitivity.
- *DOE technology for stroke treatment transferred to NIH.* DOE researchers at Lawrence Livermore National Laboratory have successfully completed the material design of a mechanical shape memory polymer device that can be introduced into the vessels in the brain and successfully remove a blood clot causing a stroke. This technology has the potential of significantly reducing deaths from one of the major disease killers in the United States. The DOE has successfully transferred this technology to the NIH, which will fund initial clinical evaluation of the device.
- *A Multitracer Technique for Diagnosing the Root Cause of Obesity.* Brookhaven National Laboratory (BNL) scientists have developed a multi-radiotracer (carbon-11-raclopride, fluorine-18-FDG and carbon-11 cocaine combined) PET imaging approach which shows that obese individuals have an understimulated brain dopamine system similar to drug abusers. Dopamine is a brain chemical that is important in reward and well-being. This disruption of dopamine function may account for pathological overeating, which has parallels in the drug abuser who cannot stop taking the drug even when this behavior is detrimental. This suggests that improving dopamine function may be a useful treatment strategy for obesity, a major public health problem affecting more than 25% of the United States population.
- *New Toluene Radiotracer Developed to Study Inhalant Abuse*. BNL scientists have successfully labeled the volatile chemical toluene with carbon-11 for PET imaging. Using carbon-11 toluene for PET imaging, Brookhaven scientists have shown for the first time that toluene, the most common solvent of abuse, rapidly enters the brain and localizes on the same areas of the brain that are affected by cocaine and other drugs of abuse. This new approach and the new knowledge that it is generating are an important step in understanding and eventually treating addiction to inhalants. The abuse of inhalants ("huffing") by children is a growing problem worldwide.
- *PET Imaging Study Provides New Knowledge For Improved Targeting of Attention Deficit Hyperactivity Disorder.* For more than 40 years, attention deficit hyperactivity disorder (ADHD) has been treated with Ritalin, a stimulant. Yet there have been no studies showing how Ritalin affects the human brain. Using PET imaging with radiotracers (carbon-11 raclopride, and carbon-11 cocaine) Brookhaven researchers have shown for the first time in the human brain that Ritalin elevates

dopamine, a signaling chemical that is important in regulating attention. This new knowledge will form the groundwork for designing better drugs to treat ADHD.

Subprogram Goals

Develop innovative radiopharmaceuticals for diagnosis and treatment of human disease and develop novel imaging instrumentation and technologies to precisely visualize and measure biological functions, including gene expression, and more accurately detect human disease.

Performance Indicator

Number of novel imaging devices delivered.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
(Novel cell-directed cancer therapies)	(Novel cell-directed cancer therapies)	(Novel cell-directed cancer therapies)
BNCT program at MIT/Harvard was successfully transferred to the National Cancer Institute for conduct of clinical trials. [Goal Met]	Number of tumor therapeutic agents that perform sufficiently well in pre-clinical evaluations to deserve consideration for clinical trials by NIH and/or private industry.	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 and success in developing a high flux epithermal beam suitable for clinical use at the MIT reactor.
(Radiopharmaceutical design/synthesis)	(Radiopharmaceutical design/synthesis)	(Radiopharmaceutical design/synthesis)
A novel radiotracer was developed that can be used to detect early lesions in Alzheimers Disease. [Goal Met] A multi-radiotracer detection system was developed to detect biochemical abnormalities in brains of patients with obesity. [Goal Met] A toluene radiotracer was developed to study inhalant abuse. [Goal Met]	Develop unique radiopharmaceutical tracers that will enable PET medical imaging to more precisely diagnose neuro-psychiatric illnesses (Alzheimer's Disease, Parkinson's Disease, multiple sclerosis, and others) and cancer in humans. This research is closely coordinated with the NIH Institutes of Drug Abuse, of Mental Health, and of Neurological Disorders and Stroke. Develop innovative methods and instrumentation to image gene expression in real time in cells, tissues and whole organisms.	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 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 2002 Results	FY 2003 Targets	FY 2004 Targets
(Imaging Sciences) Micro-PET technology was transferred to industrial partners for commercialization. [Goal Met] A prototype artificial retina device was successfully inserted into the eye of a blind person. [Goal Met] A PET imaging system was used to pinpoint abnormalities in the brains of patients with attention deficit disorder. [Goal Met] An ultra sensitive cantilever detection system, even more sensitive than currently used technology, was developed as a potential new clinical tool to detect prostate specific antigen (PSA). [Goal Met]	(Imaging Sciences) Enhance 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. In close partnership with NIH, develop novel technology and instrumentation for imaging single molecules, genes, cells, organs, and whole organisms in real time under natural physiological conditions with a high degree of precision, including MRI, PET, and SPECT. 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.	(Imaging Sciences) Complete the design, computational modeling and construction of a prototype high-density micro array device (artificial retina) and have implanted the test device into the canine eye. The device will receive light signals from an external camera and convert the photons to electrical signals to be transmitted to the brain. The biological compatibility and ability of the device to transmit signals to the canine brain will be measured. Complete the development of a radiotracer imaging system that approaches the fundamental limit of spatial resolution and detector sensitivity to be applied to the diagnosis of small cancers. Complete the prototype design of MRI and PET instruments capable of performing functional images on moving animals including the design of novel dipole magnets, fiber-optic arrays, miniature positron detectors, and the construction of algorithms to detect and correct for motion during image acquisition. Develop an array of biological sensors employing laser cantilever technology, protein-receptor detection systems that rely on fluorescent resonant energy transfer, and microspectroscopy platform systems.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Medical Applications	116,085	38,701	38,642	-59	-0.2%
Measurement Science	2,555	5,961	5,952	-9	-0.2%
SBIR/STTR	0	1,186	1,254	+68	+5.7%
Total, Medical Applications and Measurement Science	118,640	45,848	45,848	0	--

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Medical Applications	**116,085**	**38,701**	**38,642**
▪ **Novel cell-directed cancer therapies**	**9,699**	**4,870**	**4,862**

In FY 2004, BER continues to support fundamental research on the therapeutic use of ionizing radiation that may be achieved with radionuclide therapy and novel methods of tumor targeting. Recent therapeutic successes employing antibodies or ligands linked to radionuclides has grown out of fundamental combinatorial radiochemistry supported by BER. 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.

The BER supported Boron Neutron Capture Therapy clinical safety studies at the Brookhaven National laboratories and at MIT/Beth Israel Hospital were completed in FY 2002. BER funding of the MIT medical reactor continues with the aim of developing the optimum neutron beam delivery for animal studies and to support NIH research trials of BNCT cancer treatment in humans.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

▪ **Radiopharmaceutical Design and Synthesis**	**23,570**	**24,445**	**24,407**

In FY 2004, BER will continue to 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 with each other 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 leading to more effective therapy. If labeled with high energy-emitting

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

radioisotopes, the substrate molecules, carrying the radiation dose may be powerful tools for targeted molecular therapy especially of cancer. The program will continue to support development of new radiotracer and radiopharmaceutical molecules for PET imaging applications (e.g., normal and abnormal brain biochemistries in response to normal and abnormal brain functions in health and disease).

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.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

	FY 2002	FY 2003	FY 2004
▪ **Imaging Sciences Instrumentation and Research**	**13,994**	**9,386**	**9,373**

In FY 2004, BER will emphasize support in fundamental research to facilitate the development of imaging systems relevant to solving critical problems related to the Nation's health. This program capitalizes on the unique resources at the National Laboratories in the fields of computational modeling, detector development, multimodal spectroscopy, high-field magnet development and microelectronics. Imaging instrumentation and technology being developed includes: **(**1) the development of a high-density microelectronic array (the artificial retina) that can be packaged into a tiny device to be implanted in to the back of the eye. The device will be used for the treatment of the major causes of blindness in the United States, retinitis pigmentosa and age-related macular degeneration; 2) PET and MRI instruments that will be used to study brain function in the awake individual. These imaging devices will obviate the necessity of anesthetizing animals (inducing coma) to acquire brain images and may also have great potential for use with infants; 3) a range of image detector systems that will be more sensitive and cost effective than current instrumentation used in the diagnosis of human disease; and 4) novel biosensor devices that can detect specific molecules or biological processes important in human biology and disease and convert this

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

information into a measurable signal. These devices can be adapted to rapidly diagnose microorganisms in the field.

BER's imaging technology program works closely with other Federal Agencies, especially the National Institutes of Health, to help coordinate and focus the research efforts at the National Laboratories. Federal Agency partners include National Institutes of Health Biomedical Engineering Consortium (BECON) and the National Institute of Bioengineering and Bioimaging (NBIB).

The research activities in this subprogram are principally carried out at National Laboratories.

	FY 2002	FY 2003	FY 2004
▪ **Congressional Direction**	**68,822**	**0**	**0**

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

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

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.

Measurement Science	**2,555**	**5,961**	**5,952**

In FY 2004, 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.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

SBIR/STTR..	**0**	**1,186**	**1,254**

In FY 2002 $3,008,000 and $193,000 were transferred to the SBIR and STTR programs, respectively. FY 2003 and FY 2004 amounts are estimated requirements for the continuation of these programs..

Total, Medical Applications and Measurement Science	**118,640**	**45,848**	**45,848**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Medical Applications & Measurement Science	
▪ Activities will continue at near FY 2003 levels. Decrease is due to the increase in STTR allocation.	-68
SBIR/STTR	
▪ SBIR/STTR increases due to STTR allocation increase	+68
Total Funding Change, Medical Applications and Measurement Science	0

Construction

Mission Supporting Goals and Measures

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 2002	FY 2003	FY 2004	$ Change	% Change
Construction..	11,405	0	0	0	0.0%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Construction	**11,405**	**0**	**0**

- The Laboratory for Comparative and Functional Genomics at Oak Ridge National Laboratory will provide a modern research facility to help understand the function of newly discovered human genes, to support DOE research programs and to house 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.

  BER will meet the cost and schedule milestones for construction of facilities and major items of equipment within 10% of baseline estimates.

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Construction	
▪ Funding for the construction of the Laboratory for Comparative and Functional Genomics is completed in FY 2002.	0

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
General Plant Projects	4,991	4,811	4,811	0	--
Capital Equipment	37,263	17,047	19,625	+2,578	+15.1%
Total Capital Operating Expenses	42,254	21,858	24,436	+2,578	+11.8%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2002	FY 2003	FY 2004	Unapprop-riated Balance
01-E-300, Laboratory for Comparative and Functional Genomics, ORNL	13,900	2,495	11,405	0	0	0
Total, Construction		2,495	11,405	0	0	0

Basic Energy Sciences

Program Mission

The mission of the Basic Energy Sciences (BES) program – a multipurpose, scientific research effort – is to foster and support fundamental research to expand the scientific foundations for new and improved energy technologies and for understanding and mitigating the environmental impacts of energy use. The portfolio supports work in the natural sciences, emphasizing fundamental research in materials sciences, chemistry, geosciences, and aspects of biosciences. 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.

Overview:

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 evolve 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 BES program is one of the Nation's largest sponsors of research in the natural sciences and is uniquely responsible for supporting fundamental research in materials sciences, chemistry, geosciences, and aspects of biosciences impacting energy resources, production, conversion, efficiency, and the mitigation of the adverse impacts of energy production and use. In FY 2002, the program funded research in more than 166 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 35% of the program's research activities sited at academic institutions.

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 samples. 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.

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;
- 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;
- processes for extraction of radioactive and hazardous metal ions from solutions for nuclear fuel purification/reprocessing and for cleanup of radioactive wastes; and
- a host of new instruments, e.g. instruments based on high-temperature superconductors 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 the most fundamental questions in materials sciences, chemistry, and the other disciplines supported by BES.

The future holds even greater promise, largely because of our new atom-by-atom understanding of matter and the subsequent unprecedented ability to design and construct new materials with properties that are not found in nature. This atomic-level understanding touches all of the disciplines supported by BES. Scientific endeavors that once were considered “observational” – endeavors as diverse as plant sciences or metal and alloy sciences – now are understood at the atomic level. This understanding that explains phenomena in these diverse disciplines also inextricably links them, providing the foundation for the remarkable nanoscale science revolution that is now upon us.

This new atomic-level understanding that allows us to see how the machinery of life functions, atom-by-atom, comes from the great synchrotron x-ray and neutron scattering sources, the electron microscopes, and other atomic probes as well as the terascale computers. The BES program has played a major role in enabling the coming revolution. This impact results from a deliberate philosophy of identifying seminal challenges and establishing both facilities and coordinated programs that transcend what individuals alone can do. The program in nanoscale science, including the formation of Nanoscale Science Research Centers, continues that philosophy.

The new millennium will take us deep into the world of complex nanostructures. Here, simple structures interact to create new phenomena and assemble themselves into devices. Here also, large complicated structures can be designed atom by atom for desired characteristics. We will be able to build atomic scale structures that interact with biological or inorganic systems and alter their functions. We will design new tiny objects "from scratch" that have unprecedented optical, mechanical, electrical, or chemical properties that address needs of human society.

New tools, new understanding, and a developing convergence of the disciplines of physics, chemistry, materials science, biology, computation, and engineering will enable us to build on our 20th century successes and begin to ask and solve questions that were, until the 21st century, the stuff of science fiction.

How We Work:

To ensure that the most scientifically promising research is supported, the BES program engages in long-range planning and prioritization; regular external, independent review of the supported research to ensure quality and relevance; and evaluation of program performance through establishment and subsequent measurement against goals and objectives. These activities rely heavily on input from external sources including workshops and meetings of the scientific community, advice from the federally chartered Basic Energy Sciences Advisory Committee (BESAC), Interagency Working Groups, and reports from other groups such as the National Academy of Sciences. To accomplish its mission, the BES Program supports research in both universities and DOE laboratories; plans, constructs, and operates world-class scientific user facilities; and maintains a strong infrastructure to support research in areas of core competencies. Some of the details of how we work are given in the sections below.

Advisory and Consultative Activities:

Charges are provided to BESAC by the Director of the Office of Science. During the past few years, BESAC has provided advice on new directions in nanoscale science and complex systems; on the operation of the major scientific user facilities; on the need for new, “next-generation” facilities for x-ray, neutron, and electron-beam scattering; on the quality of the BES program management and its consequent impacts on the program portfolio; on new directions in research relating to specific aspects of fundamental science such as catalysis or biomolecular materials; and on the fundamental research challenges posed by the Department’s energy missions. BESAC also led the Office of Science workshop on performance measurement. Other studies are commissioned as needed using the National Academy of Science’s National Research Council and other independent groups.

Facility Reviews:

Facilities are reviewed using (1) external, independent review committees operating according to the procedures established for peer review of BES laboratory programs and facilities (http://www.science.doe.gov/bes/labreview.html) and (2) a specially empanelled subcommittee of BESAC. During the past six years, BESAC subcommittees have reviewed the synchrotron radiation light sources, the neutron scattering facilities, and the electron-beam microcharacterization facilities. The reports of these reviews are available on the BES website (http://www.science.doe.gov/bes/BESAC/reports.html). Regardless of whether a review is by an independent committee charged by a BES program manager or by a BESAC subcommittee charged by the Director of the Office of Science, the review has standard elements. Important aspects of the reviews include assessments of the quality of research performed at the facility; the reliability and availability of the facility; user access policies and procedures; user satisfaction; facility staffing levels; R&D activities to advance the facility; management of the facility; and long-range goals of the facility. These reviews have identified both best practices and substantive issues, including those associated with mature facilities. For example, the reviews clearly highlighted the change that occurred as the light sources transitioned from a mode in which they served primarily expert users to one in which they served very large numbers of inexperienced users in a wide variety of disciplines. The light sources experienced a quadrupling of the number of users in the decade of the 1990s. This success and its consequent growing pains were delineated by our review committees, which made recommendations that helped guide existing light sources and neutron scattering facilities as well as the new Spallation Neutron Source now under construction.

Facilities that are in design or construction are reviewed according to procedures set down in DOE Order 413.3 *Program and Project Management for Capital Assets* and in the Office of Science *Independent Review Handbook* (http://www.science.doe.gov/SC-80/sc-81/docs.html#DOE). In general, once a project has entered the construction phase (e.g., projects such as the Spallation Neutron Source or the Center for Nanophase Materials Sciences), it is reviewed with an external, independent committee biannually. These Office of Science construction project reviews, enlist experts in the technical scope of the facility under construction and its costing, scheduling, and construction management.

Program Reviews:

All research projects supported by the BES program undergo regular peer review and merit evaluation based on procedures set down in 10 CFR Part 605 for the extramural grant program and in an analogous process for the laboratory programs (http://www.science.doe.gov/bes/labreview.html). These peer review and merit evaluation procedures are described within documents found at (http://www.science.doe.gov/bes/peerreview.html). These evaluations assess:

(1) Scientific and/or technical merit or the educational benefits of the project;
(2) Appropriateness of the proposed method or approach;
(3) Competency of personnel and adequacy of proposed resources;
(4) Reasonableness and appropriateness of the proposed budget; and
(5) Other appropriate factors, established and set forth by SC in a notice of availability or in a specific solicitation.

In addition, on a rotating schedule, BESAC will review the major elements of the BES program using a Committee of Visitors (COVs). COVs are charged with (1) assessing the efficacy and quality of the processes used to solicit, review, recommend, monitor, and document proposal actions and (2) assessing the breadth and depth of portfolio elements and the national and international standing of the elements. The first review, which was held in FY 2002, assessed the chemistry activities. The next two years will see similar reviews of the materials sciences and engineering activities and the x-ray and neutron scattering scientific user facilities. It is intended that this cycle be repeated every three years, so that all elements of the BES program will be reviewed once every three years.

Planning and Priority Setting:

Because the BES program supports research covering a wide range of scientific disciplines as well as a large number of major scientific user facilities, planning is an ongoing activity. Many long-range planning exercises for elements of the BES program are performed under the auspices of BESAC. Prioritization within each of these program elements is achieved via such studies. Prioritization across the entirety of the BES program is more complex than that for a homogeneous program where a single planning exercise results in a prioritization.

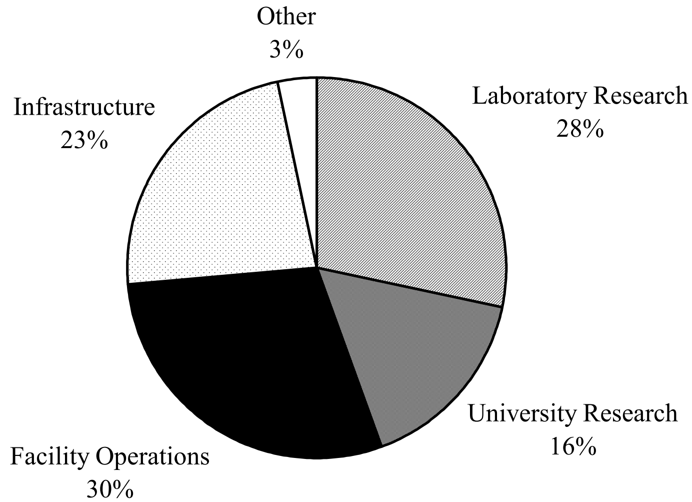
Inputs to our prioritization include overall scientific opportunity, projected investment opportunity, DOE mission need, and Administration and Departmental priorities. During the past few years, these considerations have led to: increased investments in science at the nanoscale to take advantage of the remarkable knowledge gained from atomic-scale understanding of materials; increased investments for operations of the major user facilities in recognition of the quadrupling of users in the past decade and to reap the rewards of the capital investments in the facilities themselves; increased investments for instrumentation at the facilities so that the quality of the instruments will match the world-class quality of the facilities; and increases for targeted program areas for which both scientific opportunity and mission need are high (e.g., catalysis) or for which BES represents the sole U.S. steward of the field (e.g., heavy-element chemistry). Construction of new user facilities such as the Spallation Neutron Source or upgrades to existing facilities such as the High Flux Isotope Reactor or the Stanford Synchrotron Radiation Laboratory follow from input from BESAC and National Academy of Sciences studies and from broad, national strategies that include the input from multiple federal agencies.

The FY 2004 budget request continues priorities established in the past three years. Construction of the Spallation Neutron Sources continues in accord with the established baseline. A significant investment in the area of nanoscale science includes construction funding for three Nanoscale Science Research Centers at Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, and the combination of Sandia National Laboratories and Los Alamos National Laboratories. Project Engineering Design funding is requested for the Nanoscale Science Research Center at Brookhaven National Laboratory. Finally, support for a Major Item of Equipment (MIE) is requested for the fifth and final Nanoscale Science Research Center at Argonne National Laboratory. That Center is being built in partnership with the State of Illinois, which is providing $36,000,000 in FY 2003 and FY 2004 for the construction of the building. BES funding will provide clean rooms, instrumentation, and ultimately operations support for the Center. Project Engineering Design funding is also provided for the Linac Coherent Light Source, a 4th generation light source that will provide orders of magnitude higher intensities of x-ray light than do current synchrotron radiation light sources.

How We Spend Our Budget:

The BES program has three major program elements: research, facility operations, and construction and laboratory infrastructure support. Approximately 35% of the research funding goes to support work in universities with most of the remainder going to support work in DOE laboratories. This ratio has remained constant for more than a decade and is determined largely by peer review of proposals submitted to the BES program. The facility operations budget has grown relative to the research budget over the past decade, reflecting the commissioning of new and upgraded facilities as well as the increased importance of these facilities in enabling the research of thousands of researchers across the Nation. Construction remains a significant budget component in FY 2004 and includes the Spallation Neutron Source, various Nanoscale Science Research Centers, and the design of the Linac Coherent Light Source.

BASIC ENERGY SCIENCES
FY 2004



Research:

The BES program is one of the Nation's largest supporters of fundamental research in materials sciences, chemistry, geosciences, and aspects of biosciences. Research is supported in both DOE laboratories and universities. While peer review of all research ensures outstanding quality and relevance, each of the two research sectors has unique characteristics and strengths.

National Laboratory Research: Research sited at DOE laboratories often takes advantage of the premier scientific user facilities for x-ray, neutron, and electron beam scattering at the laboratories as well as other specialized facilities, such as hot cells, which are not typically found at universities. Mission critical research is also sited at DOE laboratories when it outside of the mainstream of research supported at universities, e.g., heavy-element chemistry or combustion chemistry. Research sited at DOE laboratories is very often collocated with and sometimes cofunded with research activities of the DOE technology offices, providing a synergism not available in universities. Finally, research that requires strong interdisciplinary interactions or large teams of closely collaborating researchers is also well suited to DOE laboratories.

University Research: Universities provide access to the Nation's largest scientific talent pool and to the next-generation of scientists. Development of the workforce through the support of faculty, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills is a high priority. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research. Furthermore, engaging faculty and students in the work of the BES program develops a broad appreciation for the basic research needs associated with the program.

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 Indicators

Validation of results by merit review with external peer evaluation.

Validation of program directions by Basic Energy Sciences Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
BES used expert advisory committees and rigorous peer review to ascertain that the research performed by investigators in universities and DOE laboratories was focused and outstanding. (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, relevance, and national and international leadership of BES programs, the chemical sciences activities were reviewed using a BESAC-chartered Committee of Visitors. (SC4-1) [Met Goal]	As part of the continuing, high-level review of the management processes and the quality, relevance, and national and international leadership of BES programs, review the materials sciences and engineering activities using a BESAC-chartered Committee of Visitors. Implement recommendations from FY 2002 BESAC-chartered Committees of Visitors. (SC4-1)	Implement recommendations from FY 2003 BESAC-chartered Committees of Visitors. (SC4-1)
	Through a BESAC-chartered workshop on "Basic Research Needs to Assure a Secure Energy Future," evaluate future basic research directions appropriate for all activities of the BES program. (SC4-1)	Implement recommendations and new directions resulting from the BESAC-chartered workshop on "Basic Research Needs to Assure a Secure Energy Future." (SC4-1)
Selected aspects of the BES activities were evaluated using BES and BESAC workshops to direct activities toward international leadership and relevance to emerging technologies. (SC4-1) [Met Goal]	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 in accordance with these results. (SC-4-1)	Evaluate aspects of the BES activities using workshops with the goal of directing the research activities toward international leadership and relevance to emerging technologies. 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 Indicators

Validation of results by merit review with external peer evaluation.

Validation of program directions by Basic Energy Sciences Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
PED was begun on three Nanoscale Science Research Centers. PED funding was obligated to LBNL (6% complete), ORNL (60% complete), and SNL (24% complete). (SC4-2). [Met Goal]	Begin construction of one Nanoscale Science Research Center (NSRC), meeting the cost and timetables within 10 percent of the baselines given in the construction project data sheets for Project Number 03-R-312. Continue project engineering design (PED) activities to establish construction baselines on the two other NSRCs. (SC4-2)	Continue construction of one Nanoscale Science Research Center scheduled for completion in FY 2006 and begin construction on two others scheduled for completion in FY 2007, meeting the cost and timetables within 10 percent of the baselines given in the construction project data sheet. Initiate PED activities to establish construction baselines on one additional Nanoscale Science Research Center. Begin MIE on the fifth and final Nanoscale Science Research Center. (SC4-2)
	Establish the instrument suites and identify fabrication capabilities for the new NSRC based upon user community input at national workshops held in late FY 2001 and FY 2002. (SC4-2)	Establish instrument suites and identify fabrication capabilities for the Nanoscale Science Research Centers based upon user community input at national workshops. (SC4-2)
In FY 2002, there were 46 new grants awarded to universities and 12 projects at DOE laboratories were initiated in selected areas of nanoscale science, engineering, and technology. (SC4-2) [Met Goal]		

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 Indicators

Validation of results by merit review with external peer evaluation.

Validation of program directions by Basic Energy Sciences Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
	Select and begin upgrade/fabrication of 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)	Continue fabrication of 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)

SC4-4: 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 Indicators

Validation of results by merit review with external peer evaluation.

Validation of program directions by Basic Energy Sciences Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
	Select and begin upgrade/fabrication of instruments at the BES neutron scattering facilities, 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)	Continue fabrication of instruments at the BES neutron scattering facilities, 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)

SC7-4: 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 Indicators

Validation of results by merit review with external peer evaluation.

Validation of program directions by Basic Energy Sciences Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
BES scientific user facilities were maintained and operated so that the unscheduled downtime on average was less than 10 percent of the total scheduled operating time. (SC7-4) [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. (SC7-4)	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. (SC7-4)
The cost and schedule milestones for upgrades and construction of scientific user facilities were met. (SC7-4) [Met Goal]	Maintain the cost and schedule milestones within 10 percent for upgrades and construction of scientific user facilities. (SC7-4)	Maintain the cost and schedule milestones within 10 percent for upgrades and construction of scientific user facilities. (SC7-4)
Construction of the Spallation Neutron Source met the cost and schedule milestones within 10 percent of the baselines in the construction project data sheet, project number 99-E-334. At the end of FY 2002, construction was 47 percent complete. (SC7-4) [Met Goal]	Continue construction of the Spallation Neutron Source meeting the cost and schedule milestones within 10 percent of the construction project data sheet baselines. At the end of FY 2003, construction will be 61 percent complete. (SC7-4)	Continue construction of the Spallation Neutron Source, meeting the cost and schedule milestones within 10 percent of the construction project data sheet baselines. At the end of FY 2004, construction will be 80 percent complete. (SC7-4)
The upgrade of the SPEAR storage ring at the Stanford Synchrotron Radiation Laboratory met the cost and schedule milestones within 10 percent. At the end of FY 2002, the upgrade was 70% complete. (SC7-4) [Met Goal]	Complete the upgrade of the SPEAR 3 storage ring at the Stanford Synchrotron Radiation Laboratory), maintaining cost and schedule within 10 percent of baselines.	
	Begin PED of the Linac Coherent Light Source at the Stanford Linear Accelerator Facility. At the end of FY 2003, PED will be 18 percent complete. (SC7-4)	Continue PED of the Linac Coherent Light Source at the Stanford Linear Accelerator Facility. At the end of FY 2004, PED will be 40 percent complete. (SC7-4)

Program Assessment Rating Tool (PART) Assessment

The Office of Management and Budget's (OMB) PART assessment of the BES program rated the program highly for having a "well defined mission, merit-based reviews for awarding contracts and grants, and highly-regarded large project management practices." BES was rated lower for planning and results because of BES's "current lack of adequate long-term and annual performance measures" though OMB did acknowledge "the program has made significant strides toward developing such measures despite the problems inherent in measuring and predicting scientific progress."

The BES program was found to be focused, well managed, and was the first Office of Science program to institute a process whereby an ad hoc panel of outside experts favorably reviewed the program's research portfolio and processes. OMB also noted a recent GAO report validating the BES program's merit-based peer review process for awarding contracts and grants.

To address OMB's two concerns for the BES program: 1) The FY 2004 budget requests funds to operate the BES user facilities at 99 percent of maximum capacity, and to continue work on the design and construction of four new nanoscale science research facilities; and 2) the BES program will work with the DOE's Office of Science and Chief Financial Officer, and OMB to reform the BES performance measures and goals to more accurately predict future scientific progress in a scientifically justifiable and meaningful manner.

Significant Program Shifts

In FY 2004, construction will proceed on three Nanoscale Science Research Centers (NSRCs), project engineering design will be initiated on the fourth NSRC, and a Major Item of Equipment will be initiated for the fifth and final NSRC. NSRCs are user facilities for the synthesis, processing, fabrication, and analysis of materials at the nanoscale. They are designed to enable the nanoscale revolution by collocating multiple research disciplines and a wide variety of state-of-the-art instrumentation in a single building. NSRCs will be sited adjacent to or near an existing BES synchrotron or neutron scattering facility to enable rapid characterization of newly fabricated materials.

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.

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. Planning for the NSRCs has included substantial participation by the research community through a series of widely advertised and heavily attended workshops attracting up to 450 researchers each.

The following table summarizes the BES investments in research at the nanoscale.

Nanoscale Science Research Funding

	TEC	TPC	FY 2002 Enacted	FY 2003 Request	FY 2004 Request
Research					
Materials Sciences and Engineering			58,184	66,645	66,795
Chemical Sciences, Geosciences, and Biosciences			27,318	27,395	28,360
Capital Equipment					
Major Item of Equipment -- ANL, Center for Nanophase Materials			0	0	10,000
Nanoscale Science Research Centers					
PED – All sites	20,000		3,000	11,000	3,000
Construction					
BNL, Center for Functional Nanomaterials	70-85,000	TBD	0	0	0
LBNL, Molecular Foundry	83,700	85,000	0	0	35,000
ORNL, Center for Nanophase Materials Sciences	64,000	65,000	0	24,000	20,000
SNL/A and LANL, Center for Integrated Nanotechnologies	73,800	75,800	0	0	29,850
Total BES Nanoscale Science Funding			88,502	129,040	193,005

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) activity is a set of coordinated investments across all Office of Science mission areas with the goal to achieve breakthrough scientific advances through computer simulation that were impossible using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. By exploiting advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-discipline collaboration among the scientific disciplines, computer scientists and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can fully exploit terascale computing and networking resources. The program will bring simulation to a parity level with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate prediction, plasma physics, particle physics, astrophysics and computational chemistry.

Scientific Facilities Utilization

The BES program request supports 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 2003. 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.

Two tables follow: The first shows the hours of operation and numbers of users for the major scientific user facilities – the synchrotron radiation sources and the neutron scattering facilities. The second shows the cost and schedule variances for the construction projects and for large (>$20,000,000) Major

Items of Equipment. Note: Cost Variance is the difference between the value of the physical work performed and the actual cost expended. A negative result is unfavorable and indicates the potential for a cost overrun. Schedule variance is the difference between the value of the physical work performed and the value of the work planned. A negative result is unfavorable and indicates that the project is behind schedule. Variance data are shown as percents. They are shown against the project's performance measurement baseline that includes cost and schedule contingency and are as of the end of each fiscal year. All projects have met or are on schedule to meet all Level 0 and Level 1 Milestones, which are shown in the table.

Hours of Operation and Numbers of Users for the Synchrotron Light Sources and Neutron Scattering Facilities	FY 2000 Actual	FY 2001 Actual	FY 2002 Actual	FY 2003 Request Estimate	FY 2004 Request Estimate
ALL FACILITIES					
Maximum Hours.....................................	37,100	37,100	37,100	37,100	37,100
Scheduled Hours	30,937	27,563	31,215	37,100	37,100
Unscheduled Downtime	2%	4%	4%	<10%	<10%
Number of Users	6,533	6,982	7,608	7,380	8,280
ADVANCED LIGHT SOURCE					
Maximum Hours	5,700	5,700	5,700	5,700	5,700
Scheduled Hours	5,651	5,468	5,236	5,700	5,700
Unscheduled Downtime	5%	4%	7%	<10%	<10%
Number of Users	1,036	1,163	1,385	1,300	1,500
ADVANCED PHOTON SOURCE					
Maximum Hours	5,700	5,700	5,700	5,700	5,700
Scheduled Hours	5,047	5,000	4,856	5,700	5,700
Unscheduled Downtime	6%	4%	3%	<10%	<10%
Number of Users	1,527	1,989	2,299	1,800	2,400
NATIONAL SYNCHROTRON LIGHT SOURCE					
Maximum Hours	5,700	5,700	5,700	5,700	5,700
Scheduled Hours	4,980	5,556	5,818	5,700	5,700
Unscheduled Downtime	0%	0%	3%	<10%	<10%
Number of Users	2,551	2,523	2,413	2,500	2,500
STANFORD SYNCHROTRON RADIATION LABORATORY					
Maximum Hours	5,300	5,300	5,300	5,300	5,300
Scheduled Hours	4,280	4,781	4,706	5,300	5,300
Unscheduled Downtime	3%	5%	5%	<10%	<10%
Number of Users	895	907	800	900	1,000
HIGH FLUX ISOTOPE REACTOR					
Maximum Hours	6,100	6,100	6,100	6,100	6,100
Scheduled Hours	6,262	8	4,111	6,100	6,100
Unscheduled Downtime	7%	0%	3%	<10%	<10%
Number of Users.....................................	269	38	76	400	400

Hours of Operation and Numbers of Users for the Synchrotron Light Sources and Neutron Scattering Facilities	FY 2000 Actual	FY 2001 Actual	FY 2002 Actual	FY 2003 Request Estimate	FY 2004 Request Estimate
INTENSE PULSED NEUTRON SOURCE					
Maximum Hours	5,000	5,000	5,000	5,000	5,000
Scheduled Hours	3,783	3,868	4,308	5,000	5,000
Unscheduled Downtime	0%	0%	0%	<10%	<10%
Number of Users	230	240	243	280	280
MANUEL LUJAN, JR. NEUTRON SCATTERING CENTER					
Maximum Hours	3,600	3,600	3,600	3,600	3,600
Scheduled Hours	934	2,882	2,180	3,600	3,600
Unscheduled Downtime	21%	18%	12%	<10%	<10%
Number of Users	25	122	163	200	200

Cost and Schedule Variance	FY 2000 Actual	FY 2001 Actual	FY 2002 Actual	FY 2003 Request Estimate	FY 2004 Request
Spallation Neutron Source					
Cost Variance	-1.7%	+0.4%	-0.3%		
Schedule Variance	-6.2%	-6.7%	-1.8%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Critical Decision 3 – Start Construction Submit PSAR	None	Linac Design Complete	Front End Beam Available to Linac Target Design Complete Linac Tunnel Beneficial Occupancy Ring Tunnel Beneficial Occupancy	None
Center for Nanophase Materials Sciences (ORNL)					
Cost Variance	N/A	N/A	0%		
Schedule Variance	N/A	N/A	0%		
Major (Levels 0 and 1) Milestones Completed or Committed to		Approved Mission Need	Approved Acquisition Execution Plan Approved Critical Decision 1 – Preliminary Baseline Range Approved Critical Decision 2 – Performance Baseline	Approve Critical Decision 3 – Start of Construction	None

Cost and Schedule Variance	FY 2000 Actual	FY 2001 Actual	FY 2002 Actual	FY 2003 Request Estimate	FY 2004 Request
SSRL SPEAR3 Upgrade					
Cost Variance	+8.3%	+0.3%	+2.0%		
Schedule Variance	-6.8%	-7.8%	-1.6%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Main magnet designs completed	Preliminary Safety Assessment Document Approved	Complete RF System Production	Approve Final Safety Assessment Document	Complete Accelerator Readiness Review
	Arc vacuum system design completed		Complete Magnet Production	Complete Vacuum System Production	Start Commission-ing
	Start vacuum system production			Complete Raft Assemblies	Approve Critical Decision 4 – Start Operations
	Test magnet prototypes			Start Major Installation	
	Start magnet production				

Construction and Infrastructure:

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.

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.

FY 2004 budget authority is requested to continue instrument R&D, design, and procurement. The drift-tube linac and cavity-coupled linac portions of the warm linac commissioning will be completed. Other commissioning activities will continue in the linac. Cryogenic refrigerator installation and system cool down will be completed and cryogenic transfer line installation and testing will be completed. Cryogenic module fabrication and installation will continue. High-energy beam transport installation and testing will be completed. Ring fabrication and assembly activities will continue. Target fabrication and assembly activities will continue. Most SNS buildings will be completed with the exception of ongoing construction work in the target and instrument facilities and the central laboratory and office building.

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. Additional information on the SNS Project is provided in the SNS construction project data sheet, project number 99-E-334.

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 billion times 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. The characteristics of the light from the LCLS will 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 preliminary Total Estimated Cost (TEC) is in the range of $200,000,000 to $240,000,000. FY 2004 Project Engineering Design (PED) funding of $7,500,000 requested for Title I and Title II design work and $2,000,000 is requested for research and development. Additional information on the LCLS Project is provided in the LCLS PED data sheet, project number 03-SC-002.

Nanoscale Science Research Centers (NSRCs)

Funds are requested for construction of NSRCs located at Oak Ridge National Laboratory, at Lawrence Berkeley National Laboratory, and at Sandia National Laboratories/Los Alamos National Laboratory. Funds are also requested for Project Engineering Design of an NSRC at Brookhaven National

Laboratory and for a Major Item of Equipment for an NSRC at Argonne National Laboratory. Additional information on the NSRCs is provided in the Construction Project data sheets, project numbers 03-R-312, 04-R-313, and 04-R-314, in the Project Engineering Design (PED) data sheet, project number 02-SC-002, and in the Materials Sciences and Engineering subprogram.

Stanford Synchrotron Radiation Laboratory (SSRL) Upgrade

Over the period FY 1999 - FY 2003, the SPEAR3 upgrade was undertaken at SSRL to provide major improvements to all existing experimental stations served by this synchrotron radiation light source. The upgrade increased injection energy from 2.3 GeV to 3 GeV to improve the energy spectrum available to users; decreased beam emittance by a factor of 7 to increase beam brightness; increased operating current from 100 mA to 200 mA to increase beam intensity; and maintained 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 were replaced in order to implement the revised lattice system. All components are housed within the existing buildings. The TEC was $29,000,000; DOE and NIH equally funded the upgrade with a total Federal cost of $58,000,000. NIH provided $14,000,000 in FY 1999, $14,000,000 in FY 2000, and $1,000,000 in FY 2001.

BES provides funding for general plant projects (GPP) and general plant equipment (GPE) for Argonne National Laboratory, Ames Laboratory, and Oak Ridge National Laboratory.

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.

	FY 2000	FY 2001	FY 2002 Enacted	FY 2003 Request	FY 2004 Request
# University Grants	1,062	1,094	1,071	1,150	1,150
Ave. Size ($ thousands/yr)	116	134	140	140	140
# Permanent Ph.D.s	3,490	3,780	3,650	3,910	3,930
# Postdocs	1,005	1,090	1,050	1,140	1,130
# Grad Students	1,640	1,780	1,700	1,820	1,820

Funding Profile

	(dollars in thousands)				
	FY 2002 Comparable Appropriation	FY 2003 Request	FY 2004 Request	$ Change	% Change
Basic Energy Sciences					
Research					
Materials Sciences and Engineering	500,033	547,577	567,711	+20,134	+36.8%
Chemical Sciences, Geosciences, and Energy Biosciences	200,227	220,015	220,914	+899	+0.4%
Subtotal, Research	700,260	767,592	788,625	+21,033	+27.4%
Construction	279,300	251,571	219,950	-31,621	-12.6%
Total, Basic Energy Sciences	979,560 [abcd]	1,019,163	1,008,575	-10,588	-1.0%

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 $15,672,000 which was transferred to the SBIR program and $940,000 which was transferred to the STTR program.

[b] Excludes $405,000 for the FY 2002 rescission contained in Section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to terrorist attacks on the United States.

[c] Excludes $2,600,000 transferred to Safeguards and Security for a FY 2002 reprogramming.

[d] Excludes $428,000 and $437,000 in FY 2002 and FY 2003 respectively, transferred to Security Operations in FY 2004 for waste management activities at the New Brunswick Laboratory.

Funding by Site [a]

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	25,089	23,041	23,634	+593	+2.6%
National Renewable Energy Laboratory	5,412	4,562	4,562	0	--
Sandia National Laboratory	25,977	25,987	52,949	+26,962	+103.8%
Total, Albuquerque Operations Office	56,478	53,590	81,145	+27,555	+51.4%
Chicago Operations Office					
Ames Laboratory	18,377	16,507	16,502	-5	--
Argonne National Laboratory – East	156,916	152,734	166,066	+13,332	+8.7%
Brookhaven National Laboratory	59,158	57,398	61,755	+4,357	+7.6%
Chicago Operations Office	105,854	84,204	84,174	-30	--
Total, Chicago Operations Office	340,305	310,843	328,497	+17,654	+5.7%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	1,784	1,494	1,494	0	--
Oakland Operations Office					
Lawrence Berkeley National Laboratory	81,885	78,691	108,247	+29,556	+37.6%
Lawrence Livermore National Laboratory	5,481	4,676	4,676	0	--
Stanford Linear Accelerator Center (SSRL)	34,073	41,716	38,943	-2,773	-6.6%
Oakland Operations Office	44,352	34,497	34,497	0	--
Total, Oakland Operations Office	165,791	159,580	186,363	+26,783	+16.8%
Oak Ridge Operations Office					
Oak Ridge Institute For Science and Education	2,203	872	872	0	--
Oak Ridge National Laboratory	398,845	343,176	257,609	-85,567	-24.9%
Total, Oak Ridge Operations Office	401,048	344,048	258,481	-85,567	-24.9%
Richland Operations Office					
Pacific Northwest National Laboratory	13,128	11,648	11,648	0	--
Washington Headquarters	1,026	137,960	140,947	+2,987	+2.2%
Total, Basic Energy Sciences	979,560 [bcde]	1,019,163	1,008,575	-10,588	-1.0%

[a] On December 20, 2002, the National Nuclear Security Administration (NNSA) disestablished the Albuquerque, Oakland, and Nevada Operations Offices, renamed existing area offices as site offices, established a new Nevada Site Office, and established a single NNSA Service Center to be located in Albuquerque. Other aspects of the NNSA organizational changes will be phased in and consolidation of the Service Center in Albuquerque will be completed by September 30, 2004. For budget display purposes, DOE is displaying non-NNSA budgets by site in the traditional pre-NNSA organizational format.

[b] Excludes $15,672,000 which was transferred to the SBIR program and $940,000 which was transferred to the STTR program.

[c] Excludes $405,000 for the FY 2002 rescission contained in Section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to terrorist attacks on the United States.

[d] Excludes $2,600,000 transferred to Safeguards and Security for a FY 2002 reprogramming.

[e] Excludes $428,000 and $437,000 in FY 2002 and FY 2003 respectively, transferred to Security Operations in FY 2004 for waste management activities at the New Brunswick Laboratory.

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, magnetism, 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 hydrocarbon 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. 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 beamlines for experimental research. Instruments on these beamlines 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.

The **Center for Nanoscale Materials**, a planned BES Nanoscale Science Research Center, will have as its focus research in advanced magnetic materials, complex oxides, nanophotonics, and bio-inorganic hybrids. An x-ray nanoprobe beam line at the Advanced Photon Source will be fabricated and run by the Center for use by its users. The facility will use existing facilities such as the Advanced Photon Source, the Intense Pulsed Neutron Source, and the Electron Microscopy Center. The State of Illinois is providing in FY 2003 and FY 2004 a total of $36,000,000 for construction of the building, which is appended to the Advanced Photon Source. BES will provide funding for clean rooms and specialized equipment as well as the operations following commissioning.

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 vacuum-ultraviolet (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 **Center for Functional Nanomaterials**, a planned BES Nanoscale Science Research Center, will have as its focus understanding the chemical and physical response of nanomaterials to make functional materials such as sensors, activators, and energy-conversion devices. The facility will use existing facilities such as the NSLS and the Laser Electron Accelerator facility. It will also provide clean rooms, general laboratories, and wet and dry laboratories for sample preparation, fabrication, and analysis. Equipment will include that needed for laboratory and fabrication facilities for e-beam lithography, transmission electron microscopy, scanning probes and surface characterization, material synthesis and fabrication, and spectroscopy.

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 germanium 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** (NCEM) 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, will have as its focus the interface between soft materials such as are found in living systems and hard materials such as carbon nanotubes. The Molecular Foundry will use existing facilities such as the ALS, the NCEM, and the National Energy Research Scientific Computing Center. The facility will provide laboratories for materials science, physics, chemistry, biology, and molecular biology. State-of-the-art equipment will include clean rooms, 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 macro-worlds. 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 and the Shared Research Equipment (SHaRE) program.

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

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, and programs in Fossil Energy and 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 macro-worlds. 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 billion times 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 168 colleges/universities located in 48 states. Also included are funds for research awaiting distribution pending completion of peer review results.

Materials Sciences and Engineering

Mission Supporting Goals and Measures

This subprogram extends the frontiers of materials sciences and engineering 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. The subprogram also plans, constructs, and operates the major x-ray scattering and neutron scattering scientific user facilities.

The subprogram supports basic research 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.

Selected FY 2002 Research Accomplishments:

- *Giant Magnetoresistance (GMR).* GMR is revolutionizing the magnetic recording and data storage industry by enabling major increases in data density and ease of read/write processes. GMR is the term applied to layered magnetic systems that undergo very large changes in resistance in the presence of a magnetic field. The origin of GMR and its relationship to layered structure is unknown. New experiments in which the GMR is measured with current flowing perpendicular to the layer interfaces have yielded insight into the factors underlying the effect. Measurements of the GMR in samples with quantitatively determined interfacial structure, characterized by microscopy and x-ray scattering, have shown a direct relationship between the GMR and the interfacial roughness. Since most GMR-based devices rely on the magnitude of the effect, these results provide guidance for their optimization by interfacial roughness tailoring.

- *Multifunctional Materials.* For the first time, organic materials that exhibit bistability simultaneously in three channels – magnetic, optical, and electrical – have been produced. The new materials have many interesting properties. In one state, they are paramagnetic (attracted to a magnetic field), infrared transparent, and electrically insulating; in the other state, they are diamagnetic (repelled by both poles of a magnet), infrared opaque, and electrically conducting. The switching between the two states is thermally driven, and a switching temperature just above technologically useful room temperature has been achieved. These multifunctional materials have the potential for use in new types of devices for electronics, computers, and data storage where multiple channels are used for reading, writing, and transferring information.

- *Transparent Electronic Devices.* Rather than ordinary glass, imagine that your window panes at home are a multi-functional wide band-gap semiconductor device that might serve as: an energy generator, a microprocessor, a detector, and a light modulator. The potential of wide-gap semiconductors is enormous, ranging from highly efficient solid-state light sources and high-density data storage to invisible monitoring devices for national security. The key in making this dream a reality is to be able to dope these materials with impurities to achieve both the n- and p-type mechanisms of electrical conduction. Achieving p-type doping had been an insurmountable problem. The root cause was found to be twofold: the spontaneous formation of native defects and the low-dopant solubility. Suppression of the defect formation was achieved by chemical design of the band structure of the semiconductor oxides. This approach has led to a family of new p-type transparent conducting materials. These studies have facilitated the experimental exploration of transparent electronic device materials.

- *World's Smallest Ultraviolet Nanolasers.* The world's smallest ultraviolet-emitting lasers, based on "nanowires" of zinc oxide, have a broad range of potential applications in fields ranging from photonics – the use of light for superfast data processing and transmission – to the so-called "lab on a chip" technology in which a microchip equipped with nano-sized light sources and sensors performs instant and detailed analyses for chemistry, biology, and medical studies. The nanolasers were fabricated using a new processing method that can grow arrays of zinc oxide nanowires between 70 and 100 nm in diameter with adjustable lengths between 2 and 10 microns. This development continues the progress in semiconductor laser research, providing new materials that extend the availability of these versatile and inexpensive light sources from the near infrared and red regions of the spectrum into the green-blue and near ultraviolet.

- *Nanotubes Increase Heat Conduction in Fluids.* Fluids containing 1 percent carbon nanotubes in oil exhibit a 250 percent increase in heat conduction. This addition of nanotubes resulted in the highest thermal conductivity enhancement ever achieved in a liquid – ten times higher than predicted by existing theories. This has required the development of new heat conduction models for solid/liquid suspensions. This research could lead to a major breakthrough in solid/liquid composites for numerous engineering applications, such as coolants for automobiles, air conditioning, and supercomputers.

- *Molecular Based Spintronic Material.* For years scientists have dreamed of separately controlling the spin and charge of the electron to create "spin electronics" or spintronics for next generation electronic devices. We have advanced one step closer to this goal with the fabrication of a new molecular solid integrating alternate layers of spin networks with organic metal networks through crystal engineering. The close proximity of the spin to the metal – less than one nanometer apart –

promises strong communication of spin and charge while allowing each to be manipulated separately. The new material is made by relatively inexpensively using bottom-up self-assembly as opposed to the elaborate and expensive top-down lithography for other semiconductor materials.

- *Deformation at the Nanoscale.* Large-scale atomic-level simulations reveal how and why conventional dislocation deformation processes in materials break down at the nanoscale. Nanostructures can experience very high internal stress levels; thus, mechanical stability and compliance represent major obstacles in the development of nanodevices. The computer simulations demonstrated that, as the grain size becomes ever smaller, a material becomes harder to deform. However, at a critical size, dislocations no longer can exist because they are comparable to that of the grains themselves, and the material suddenly softens again due to the onset of novel deformation mechanisms mediated by the grain boundaries that contain the grains. This "strongest size" was shown to be a function of not only the material itself but also the stress level to which it is subjected. These insights will enable the design of nanodevices with tailored mechanical performance capable of withstanding the very high stresses under which they often operate.

- *Nano-onions.* Carbon "nano-onions," generated by carbon-arc discharge in deionized water, are the latest entry in the fullerene family. Their structures resemble onions, with a fullerene at the core, surrounded by multiple layers of fullerene-like carbon. The arc method produces "nano-onions" with diameters from about 10 to 150 nm. These "Buckyonions" are easily fractionated on the basis of diameter by using flow field-flow fractionation, with small particles eluting before larger ones. Characterization of these "nano-onions" using electron microscopy and light scattering methods could lead to new and novel applications for these materials.

- *A Trillion Elements per Square Inch.* Magnetic storage arrays with more than a trillion elements per square inch, ultrahigh resolution field emission displays, and high resolution, on-chip macromolecular separations devices have been constructed using a new, patented technique of self-assembly of polymers. By means of routine chemical etching processes, large area arrays of nanopores (4-50 nm in diameter) with very high aspect ratios are produced in a simple, robust manner. These serve as templates for pattern transfer to substrates and as scaffolds to direct surface chemistry or electrochemical deposition of metals for the generation of ultrahigh density, multilayered nanowire arrays. The simplicity of this technique has a broad impact across many disciplines ranging from bioactivity to semiconductor devices.

- *Molecules of Gases and Water Swim Upstream.* A theoretical analysis has shown that molecules of hydrogen, oxygen, and even water can travel across conducting membranes in opposite directions from what would normally be expected. An understanding of these membranes is important in the development of advanced materials systems for energy storage such as fuel cells. The analysis pertains to a class of materials called perovskites that can, under some circumstances, conduct charge via both individual electrons and ionized atoms of hydrogen and oxygen. Individual chemical species can move in the "wrong" direction from areas where they are at a lower concentration to areas of higher concentration. This is normally explained by other driving forces that are taken into account in a quantity referred to as the chemical potential. In mixed-conducting membranes, however, the new analysis shows that neutral (uncharged) molecules can even move contrary to the gradient in the chemical potential as a result of the simultaneous, coupled transport of multiple species.

- *Ultra-Sensitive Sensors.* A new principle for chemical sensors with ultra-high sensitivity has been developed and successfully demonstrated based on computer simulations of the structure and properties of particle composites. These sensors are fabricated by dispersing electrically conducting magnetic particles into an insulating liquid, then organizing the particles into chains with a magnetic field while the liquid solidifies by polymerization. These materials are referred to as Field-Structured Composites. The particle chains conduct electricity quite well. When exposed to certain chemical vapors, the polymer absorbs the chemicals and swells. The chains are stretched ever so slightly to create gaps between the particles, resulting in conductivity decreases of ten billion or more. The unprecedented magnitude of this effect makes these materials sensitive to even trace amounts of vapors. Inexpensive, portable devices for chemical identification can be achieved by making an array of sensors, each of which is fabricated with a polymer having unique chemical affinities, so that any single vapor leaves an identifying signature on the array.

- *New Analysis Method Enables Prediction of Dendritic Pattern Formation.* Just as water freezes into the elaborate patterns of snowflakes, so do metals form highly branched patterns called dendrites. These dendrites control many aspects of the processing and microstructure that determine alloy properties and hence our ability to use materials. Dendrite patterns are controlled by minute variations of the interface between the material and its melt. While simulations have modeled the atomic processes that occur during solidification, they have proven inadequate to extract the more subtle information about the anisotropy. An entirely new method to extract the anisotropy of energy and mobility from supercomputer simulations has been devised. The critical step was the identification of a related quantity that can be calculated with sufficient precision and then used to simulate dendritic growth. Additional supercomputer simulations have exploited this new information to predict the precise nature of dendritic pattern formation in a range of materials from silicon to nickel.

- *Superconductors Show Their Stripes.* Like tigers and zebras, superconductors are distinguished by their stripes. Some physicists believe that electricity runs without resistance along "stripes" of electric charge in these materials. Stripes have now been observed for the first time in the most widely studied of the cuprate high-temperature superconductors. The material consists of planes of copper and oxygen atoms located in a square pattern. Some of the electrons are missing in these planes leaving positively charged holes that pair together to produce superconductivity. In a standard superconductor, these pairs travel through the material without hindrance producing the perfect conductivity inherent to a superconductor. However, in the cuprate materials, the copper atoms have a magnetic moment that makes conductivity in the planes difficult. Recent neutron scattering measurements made at the High Flux Isotope Reactor show that the holes form lines or stripes in the superconductor in which there are no magnetic moments. The holes can thus move along the stripe in an unimpeded manner.

- *Neutron Instrumentation for Nanoscience.* Nanoscience requires the study of structures ranging from a few nanometers to a few microns. A new neutron scattering technique for study of materials in this size range has been developed. The method uses the fact that the spin of the neutron has unique behavior in a magnetic field -- the spin precesses like a top in a magnetic field so that the total rotation angle of the spin depends on the time the neutron spends in the magnetic field. By appropriately designing the magnetic fields, the rotation angle can be made to depend on the direction of travel of the neutron with respect to some fixed spatial direction, effectively "coding" the trajectory angle into the value of the neutrons spin. This technique can easily be implemented and could be perfected in time to impact early measurements at the Spallation Neutron Source.

Selected FY 2002 Facility Accomplishments:

- The Advanced Light Source
  - ► *Superbend Magnets Extend Synchrotron Spectral Range.* Originally designed for highest brightness at longer x-ray wavelengths (soft x rays), the ALS has been retrofitted with superconducting bend magnets (superbends) that dramatically boost the synchrotron radiation intensity at shorter x-ray wavelengths (hard x rays) without disrupting the soft x-ray performance of the existing beamlines, thereby allowing the ALS to service a broader user community.
  - ► *Higher-Order-Mode Dampers Increase Storage Ring Stability.* The beam in the ALS storage ring comprises more than 300 discrete "bunches" of electrons spaced more or less equally around the ring, but interactions between the bunches can cause the beam to become unstable. Addition of antennae to the radio-frequency (RF) cavities that power the storage ring has substantially improved the reliability of the feedback system that combats beam instabilities.
  - ► *A New Radio-Frequency (RF) Feedback Loop Saves Electrical Power and Money.* Driven by the soaring costs that came with the California energy crisis, staff at the ALS found a way to reduce the electricity bill an estimated 11% by implementing a feedback loop that reduced power consumption by a klystron power amplifier without interfering with other RF-cavity controls.
  - ► *Beamline for Ultrahigh-Resolution Chemical Crystallography Commissioned.* Based on a novel miniaturized design that is low-cost yet robust and high-performance, the ALS has put into operation a new beamline that meets the demands of chemists for a tool to rapidly determine the atomic structure of molecules with sub-angstrom resolution from solid samples (crystals) as small as a few micrometers on a side.
  - ► *An Experimental Station Has Been Designed to Study Magnetic Nanostructures.* Consisting of multiple layers of magnetic and nonmagnetic materials, each only a few atoms thick, magnetic nanostructures are the foundation for advanced magnetic devices. The new station at the ALS will allow complete magnetic characterization of each layer separately with x rays that are polarized in any desired orientation.
- The Advanced Photon Source
  - ► *Operating in Top-up Mode.* One of the principal operational goals has been to run the storage ring in the "constant current" or top-up mode. Top-up mode consists of injecting a small amount of charge into the storage ring at regular intervals in order to maintain a 100 mA current. The major benefit of top-up operation is the virtual elimination of the beam lifetime (the decay of beam current over time) as a factor in further improvements or enhancements of the storage ring performance. As an example, the APS can now operate efficiently with a lower horizontal emittance, which reduces the source size by a factor of two. This reduction in size provides a smaller beam spot that can be used to illuminate smaller samples. Normally, the decrease in beam lifetime would severely reduce the average current available to the users, but with top-up, the reduction is non-existent. Top-up operation is now the standard and comprises 75 percent of the total operating time of the APS. The APS is the first synchrotron facility to have conceived and implemented top-up operation.

- ► *Canted Undulators for Increased Beamline Capacity.* New technologies devised to offset the ever-increasing demand for beamline access include the "canted undulator" configuration that produces two beamlines originating from one point on the ring.
- ► *New Information on High-Pressure Fuel Sprays.* An x-ray imaging technique devised at the Basic Energy Sciences-funded Synchrotron Radiation Instrumentation Collaborative Access Team (SRI-CAT) has produced unprecedented details of the structure of diesel fuel sprays, including the first evidence of supersonic shockwaves in sprays as they leave high-pressure fuel injectors. This information may lead to improvements in fuel injector-engine emissions and efficiency, and earned a 2002 National Laboratory Combustion & Emissions Control R&D Award from the Department of Energy.
- ► *Nanotomography of Integrated Circuit Interconnects.* A high-resolution scanning transmission x-ray microscope is providing superior 3-D images of the tiny wire interconnects and other embedded structures in computer chips without damage to the chips. This unique capability makes it possible to more easily identify and correct manufacturing problems, and ultimately to build faster, smaller, more-efficient, and more-reliable computers.
- ► *New Lens for Imaging.* An offshoot of APS expertise in x-ray beamline instrumentation is the first full-scale crystal-diffraction medical-imaging lens. Resolution with this lens is a factor of three better than with most current imaging systems. It can be applied to small test animals used by the pharmaceutical industry and to imaging small parts of the human body. There are also many possibilities for nonmedical applications, including examination of nuclear fuel elements and location of radioactive material within a larger mass.

- The National Synchrotron Light Source
  - ► *Source Development Laboratory Laser at 400 nm.* The Deep Ultra-Violet Free Electron Laser (DUV-FEL) facility marked an important milestone, generating laser light at 400 nm by the process of Self Amplified Spontaneous Emission (SASE). Achieving intensity 20,000 times higher than the spontaneous emission, the result showed that the electron beam and the undulator system can support lasing down to 88 nm, which has strong user interest in the chemical physics community.
  - ► *Soft X-ray Undulator Beamline Monochromator Upgrade.* A new water-cooled, 6-position interferometrically controlled grating chamber was installed at beamline X1B. At present, four new gratings (300, 600,1200, and 1600 lines/mm) covering the soft x-ray photon energy range from 100eV to 1600eV were outfitted. Resolving power of more than 10,000 was achieved. The high energy resolution and extended energy range provided by the new monochromator will benefit greatly all the experimental programs using the beamline, including soft x-ray resonant scattering, emission, and imaging.
  - ► *Ultra-high Vacuum Compatible Soft X-ray Scattering End Station.* A novel resonant soft x-ray scattering instrument has become operational at the X1B undulator beamline. The instrument combines the element and electronic state specificity of soft x-ray spectroscopy with x-ray diffraction, which enables the direct probing of intrinsic inhomogeneities in strongly correlated electron systems and nanoscale magnetic systems. For example, the spatial distribution of the doped holes in an epitaxial film of oxygen-doped $La_2CuO_{4+\delta}$ was determined recently using this instrument for the first time.

- *New End Station for Soft X-ray Coherent Scattering and Imaging.* To facilitate nanoscience research, imaging techniques with nanometer spatial resolution are needed. A new end station for soft x-ray coherent scattering and imaging was designed and constructed. It will be used to develop two and three dimensional diffraction imaging and tomography with tens of nanometer spatial resolution for nano-magnetic, organic, and biological systems

- The Stanford Synchrotron Radiation Laboratory

  - *Accelerator Modeling Toolbox Developed.* An interactive accelerator modeling software tool called Accelerator Toolbox has been developed that greatly increases productivity and flexibility in interactive computer modeling. By making the Accelerator Toolbox available to other laboratories via the web, a community of users has grown who share code and experience in solving similar accelerator modeling problems.

  - *High Power X-ray Monochromators Deployed.* X-ray monochromators with high-efficiency crystal cooling utilizing liquid nitrogen have been designed, fabricated and successfully installed on four high-power wiggler beam lines. Their enhanced performance under high heat loads has already resulted in significant improvements in the stability and throughput of these beam lines. These monochromators and others to be implemented will be critical elements in obtaining the ultimate performance available from the SPEAR3 accelerator when it becomes operational in 2004.

  - *Improved Microfocusing System for X-ray Microspectroscopy.* Improved tapered metal capillary focusing optics with a 5 micrometer focal spot have been successfully integrated into a new system for performing microspectroscopy measurements. These developments, which included sample scanning capabilities and software for mapping the chemical states of the elemental distributions, will ultimately be propagated to a number of beam lines to enable microspectroscopy research in biology, materials sciences, and environmental sciences.

  - *Major Progress in SSRL Beamline Upgrade Program.* A beam line upgrade program is underway whose goal is to bring all SSRL beam lines to optimal performance with SPEAR3 running at 500 mA. Improvements to date include high-stability mirror systems for the insertion device-based beam lines, new permanent magnet wigglers, a high-resolution soft x-ray monochromator, and new liquid nitrogen-cooled two-crystal x-ray monochromators. Some upgrades have been completed during the current SPEAR2 operations phase, bringing higher performance to the ongoing user research programs.

- The Intense Pulsed Neutron Source

  - *Upgrades of IPNS Instruments.* 1) A project was initiated for the development of a large-aperture, magnetic bearings-suspension, high-resolution chopper system for the HRMECS and LRMECS chopper spectrometers at IPNS. 2) A new scattering chamber for the Small Angle Diffractometer is being installed. It will improve the data quality and collection rates. 3) Through an IPNS/RIKEN collaboration a neutron compound refractive lens based on an assembly of MgF_2 single-crystal prism elements was tested on the POSY II beamline for focusing cold neutrons.

  - *Outstanding Operations at IPNS Continues.* For the fifth consecutive year, IPNS has exceeded its goal of offering at least 95% reliable operations. This includes delivering the 7 billionth pulse to the target. This accomplishment constitutes more pulses delivered to target than any other pulsed neutron source in the US. In May of 2002, IPNS was designated a Nuclear Historic Landmark by the American Nuclear Society.

- *IPNS Hosts the National Neutron and X-Ray Scattering School.* During the two-week period of August 12-23, 2002, Argonne National Laboratory once again hosted the National School on Neutron and X-Ray Scattering. The school continues to attract outstanding graduate students and post-doctoral appointees with 160 applications for the 60 positions available in 2001.

- The Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center
  - *Four Instruments Commissioned.* Four world-class neutron scattering instruments completed commissioning and entered the user program. These are HIPPO, SMARTS, Protein Crystallography Station, and Asterix. New data acquisition systems were completed and installed on the new instruments.
  - *Pharos Rebuilt.* Inelastic chopper spectrometer Pharos enjoyed substantial upgrades, including detectors on the wide-angle bank, commissioning of the new vacuum system, new data acquisition electronics and computer system, and a new chopper control system. Pharos took its first data and accepted its first users since 1997.
  - *Designed and Installed New Robust Target System, Mark II.* Using a simplified Monte Carlo model, the new target improves cooling in Mark I moderator and upper target. A beryllium reflector replaced the lead reflector, cooling was simplified, and cadmium decoupling in the reflector was removed for more robust operation. The target received first beam on July 8, 2002, as scheduled.
  - *Completed Basis for Interim Operation for actinide experiments.* The new authorization basis enabled over a dozen plutonium and uranium studies to be completed and restores an important capability to the DOE science complex.
  - *New Shutters and Interlocks.* Greater safety, reliability and performance were achieved by replacement of Personnel Access Control Systems interlocks on all flight paths, replacement of all mercury reservoirs and plumbing, and installation of a new fire detection system. Two new mechanical shutters and over 300 tons of shielding were installed to enable two new flight paths for new instruments.
  - *Proton Storage Ring Instability Tamed.* A series of successful Proton Storage Ring development tests confirmed that the "e-p instability" could be controlled at accumulated charge levels approaching 10 μC, well above the goal of 6.7μC.

- The High Flux Isotope Reactor
  - *Major Refurbishment of Reactor Vessel Completed.* The refurbishment of the pressure vessel's internal components included replacing the permanent and semipermanent beryllium reflectors and their support structures. This required maintenance was accomplished without incident and will support the substantial upgrade in neutron scattering research capabilities at HFIR.
  - *HFIR Cooling Tower Replaced.* The original 36-year-old wooden cooling tower had significant structural degradation, required excessive maintenance, and could no longer reliably support reactor operations. The more efficient replacement tower will cost less to operate and should last for the remaining life of HFIR.

- *New Thermal Neutron Beam Tubes Installed at HFIR.* The new beam tubes, which replaced existing tubes that had reached their end of life, are capable of providing more neutrons to a greater number of scientific instruments.
- *Operational Readiness Review (ORR).* The ORR at HFIR was the first to be conducted at any Category 1 DOE facility since the current ORR guidance was issued. The ORR included a comprehensive restart plan, independent-contractor and DOE reviews, and close coordination with DOE headquarters and the site office. Reactor operations were resumed on December 18, 2001
- *Facility Improvements Support Neutron Scattering Instrument Upgrades.* New monochromator drums were fabricated for the triple-axis spectrometers at HB-1, 2, and 3. A shielding tunnel and neutron guide were fabricated for HB-2, where a 20-cm-diameter beam tube was installed with beryllium inserts to support four beam lines. The resulting beam intensity is expected to be three times that of the original design for some of the instruments.

Subprogram Goals

Build leading research programs in materials sciences and engineering and provide world-class, peer-reviewed research results cognizant of DOE needs as well as the needs of the broad scientific community.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Validation of program directions by Basic Energy Sciences Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
	As part of the continuing, high-level review of the management processes and the quality, relevance, and national and international leadership of BES programs, review the materials sciences and engineering activities using a BESAC-chartered Committee of Visitors.	Implement recommendations of the BESAC-chartered Committee of Visitors for the materials sciences and engineering activities.
The ongoing BES superconductivity area was evaluated using a research workshop entitled "High Temperature Superconductivity" on April 6-8, 2002, in San Diego, CA with the goal of directing the activities toward international leadership and relevance to emerging technologies. [Met Goal]	Evaluate the following ongoing efforts using Basic Energy Sciences research workshops with the goal of directing the activities toward international leadership and relevance to emerging technologies: photovoltaics, radiation effects, and materials synthesis and processing. Publish results and continue to structure BES programs per results.	Evaluate energy storage efforts using Basic Energy Sciences research workshops with the goal of directing the activities toward international leadership and relevance to emerging technologies. Publish results and continue to structure BES programs per results.

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
A BESAC-chartered workshop on "Biomolecular Materials" held January 13-15, 2002 in San Diego, CA examined future research directions in biomolecular or biomimetic materials designed for nonmedical applications whose structure or synthesis is derived from or is inspired by biology. [Met Goal]		Implement recommendations and new program directions in materials sciences and engineering that resulted from the BESAC-chartered workshop on "Basic Research Needs to Assure a Secure Energy Future."
	Initiate R&D for the Transmission Electron Achromatic Microscope (TEAM).	Complete R&D for TEAM.

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.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Validation of program directions by Basic Energy Sciences Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
PED was begun on three Nanoscale Science Research Centers. PED funding was obligated to LBNL (6% complete), ORNL (60% complete), and SNL (24% complete). [Met Goal]	Begin construction of one Nanoscale Science Research Center scheduled for completion in FY 2006, meeting the cost and timetables within 10 percent of the baselines given in the construction project data sheet. Continue PED on two other Nanoscale Science Research Centers.	Continue construction of one Nanoscale Science Research Center scheduled for completion in FY 2006 and begin construction on two others scheduled for completion in FY 2007, meeting the cost and timetables within 10 percent of the baselines given in the construction project data sheet. Initiate PED activities to establish construction baselines on one additional Nanoscale Science Research Center. Begin MIE on the fifth and final Nanoscale Science Research Center.
	Establish instrument suites and identify fabrication capabilities for the Center for Nanophase Materials Sciences at ORNL and the Center for Nanophase Materials at ANL based upon user community input at national workshops.	Establish instrument suites and identify fabrication capabilities for the Molecular Foundry at LBNL and the Center for Integrated Nanotechnologies at SNL/LANL based upon user community input at national workshops.

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
		Establish user programs for the Nanoscale Science Research Centers prior to the commissioning of the new facilities.
Conducted a joint BESAC- and ASCAC-sponsored Workshop on Theory and Modeling in Nanoscience (May 10-11, 2002) to identify opportunities and challenges in theory, modeling and simulation that can accelerate discovery and understanding at the nanoscale. [Met Goal]		
In FY 2002, there were 27 new grants awarded to universities and 6 projects at DOE laboratories were initiated in selected materials sciences and engineering areas of nanoscale science, engineering, and technology. [Met Goal]		

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.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Validation of program directions by Basic Energy Sciences Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 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.	Continue fabrication of 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.
	Establish laboratory to laboratory agreement between SLAC and DESY (Germany) for joint R&D on 1 angstrom free-electron lasers.	

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.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Validation of program directions by Basic Energy Sciences Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
	Select and begin upgrade/fabrication of two to four instruments at the BES neutron scattering facilities, based on peer review of submitted proposals, to keep the facilities at the forefront of science. At least $5,000,000 will be awarded for fabrication of new instruments for the Spallation Neutron Source.	Continue fabrication of instruments at the BES neutron scattering facilities, based on peer review of submitted proposals, to keep the facilities at the forefront of science. At least $5,000,000 of continued funding will be made available for fabrication of new instruments for the Spallation Neutron Source.

Manage facility operations and construction to the highest standards of overall performance using merit evaluation with independent peer review.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Validation of program directions by Basic Energy Sciences Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
Construction of the Spallation Neutron Source (SNS) met the cost and schedule milestones 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 was 47 percent complete. [Met Goal]	Continue construction of the Spallation Neutron Source (SNS) meeting the cost and schedule milestones within 10 percent of the construction project data sheet baselines. At the end of FY 2003, construction of the SNS will be 61 percent complete.	Continue construction of the Spallation Neutron Source (SNS) meeting the cost and schedule milestones within 10 percent of the construction project data sheet baselines. At the end of FY 2004, construction of the Spallation Neutron Source will be 80 percent complete.
The upgrade of the SPEAR storage ring at the Stanford Synchrotron Radiation Laboratory met the cost and schedule milestones within 10 percent. At the end of FY 2002, the upgrade was 70% complete. [Met Goal]	Complete the upgrade of the SPEAR 3 storage ring at the Stanford Synchrotron Radiation Laboratory), maintaining cost and schedule within 10 percent of baselines.	

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
	Begin PED of the Linac Coherent Light Source at the Stanford Linear Accelerator Facility. At the end of FY 2003, PED will be 18 percent complete.	Continue PED of the Linac Coherent Light Source at the Stanford Linear Accelerator Facility. At the end of FY 2004, PED will be 40 percent complete.
		Implement recommendations from FY 2003 BESAC-chartered subpanel on future directions in next-generation light sources.
		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 BES management of the operations of the major x-ray and neutron scattering facilities using a BESAC-chartered Committee of Visitors.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Materials Sciences and Engineering Research	232,001	260,722	263,759	+3,037	+1.2%
Facilities Operations	268,032	274,118	290,004	+15,886	+5.8%
SBIR/STTR	0	12,737	13,948	+1,211	+9.5%
Total, Materials Sciences and Engineering	500,033	547,577	567,711	+20,134	+3.7%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Materials Sciences and Engineering Research	**232,001**	**260,722**	**263,759**
▪ **Structure and Composition of Materials**	**35,168**	**36,391**	**36,646**

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

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

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 2004, 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.

Capital equipment is provided for items such as new electron microscopes and improvements to existing instruments.

	FY 2002	FY 2003	FY 2004
▪ **Mechanical Behavior and Radiation Effects**.............................	**14,530**	**14,530**	**14,510**

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. 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 2004, 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.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

Capital equipment is provided for items such as in-situ high-temperature furnaces, and characterization instrumentation.

▪ **Physical Behavior of Materials**..	**15,735**	**15,735**	**15,713**

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 2004, 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**	**14,497**	**18,595**	**18,570**

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.

	(dollars in thousands)			
	FY 2002	FY 2003	FY 2004	

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.

In FY 2004, major activities will include continued support for 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, it should be possible to make materials that are strong, tough (resistant to impact fracture) and ductile. 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.

	FY 2002	FY 2003	FY 2004
▪ **Engineering Research**	**16,464**	**16,480**	**16,457**

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 2004, 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.

	FY 2002	FY 2003	FY 2004
▪ **Neutron and X-ray Scattering**	**35,032**	**54,277**	**54,277**

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 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.

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

Of these funds, $5,000,000 is provided in FY 2003 and in FY 2004 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.

Capital equipment is provided for items such as detectors, monochromators, mirrors, and beamline instrumentation at all of the facilities.

	FY 2002	FY 2003	FY 2004
▪ **Experimental Condensed Matter Physics**	**33,667**	**38,020**	**37,968**

This activity supports condensed matter and materials physics with 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. Research in superconductivity is coordinated with the technology programs in Energy Efficiency and Renewable Energy (EE/RE). 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 EE/RE (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 2004, major activities will include investigation of 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.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

Capital equipment is provided for crystal growth equipment, scanning tunneling microscopes, electron detectors for photoemission experiments, sample chambers, superconducting magnets and computers.

▪ **Condensed Matter Theory**	**18,007**	**18,007**	**17,982**

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, and the Center for Synthesis and Processing of Advanced Materials, which consists of collaborating projects at national laboratories, universities, and industry.

In FY 2004, 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**	**27,287**	**29,602**	**29,563**

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.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

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 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 2004, 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.

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**	**7,679**	**7,685**	**7,673**

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. The following table shows EPSCoR distribution of funds by state.

EPSCoR Distribution of Funds by State

	(dollars in thousands)		
	FY 2002	FY 2003 Estimate	FY 2004 Estimate
Alabama	814	375	815
Alaska[a]	0	0	0
Arkansas	205	65	140
Hawaii[b]	0	0	0
Idaho	0	60	0
Kansas	802	615	560
Kentucky	611	471	355
Louisiana	130	130	0
Maine	0	0	0
Mississippi	589	535	535
Montana	580	465	515
Nebraska	475	300	300
Nevada	543	325	250
New Mexico[b]	0	0	0
North Dakota	0	55	0
Oklahoma	204	65	140
Puerto Rico	435	435	375
South Carolina	558	120	140
South Dakota	0	0	0
Vermont	857	585	857
West Virginia	794	525	360
Wyoming	31	65	0
Technical Support	51	400	100
Other	0	2,094 [c]	2,231 [c]
Total	7,679	7,685	7,673

[a] Alaska became eligible for funding in FY 2001.

[b] Hawaii and New Mexico became eligible for funding in FY 2002.

[c] Uncommitted funds in FY 2003 and FY 2004 will be competed among all EPSCoR states.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▪ **Neutron Scattering Instrumentation at the High Flux Isotope Reactor**	**2,000**	**2,000**	**2,000**

Capital equipment funds are provided for new and upgraded instrumentation, such as spectrometers, defractometers, and detectors.

▪ **Linac Coherent Light Source (LCLS)**	**1,500**	**0**	**2,000**

Research and development (R&D) funds are provided to support the physics design of several key LCLS components: the radiofrequency photocathode gun, the linac, the undulator, and the beam optics. These R&D activities will be carried out at SLAC and other collaborating institutions in order to reduce the technical risk and provide more confidence in the project's cost and schedule estimates prior to establishing a project performance baseline.

▪ **Nanoscale Science Research Centers**	**1,160**	**100**	**400**

Funds are provided for three Nanoscience Research Centers to support pre-operational activities leading up to the start of research operations. These Centers are the Center for Nanophase Materials Sciences (CNMS) located at ORNL, the Molecular Foundry (TMF) located at LBNL, and the Center for Integrated Nanotechnologies (CINT) located at Sandia National Laboratories.

▪ **SPEAR3 Upgrade**	**8,300**	**9,300**	**0**

Over the period FY 1999 - FY 2003, the SPEAR3 upgrade (funded in both BES subprograms) was undertaken at SSRL to provide major improvements to all existing experimental stations served by this synchrotron radiation light source. The upgrade increased injection energy from 2.3 GeV to 3 GeV to improve the energy spectrum available to users; decreased beam emittance by a factor of 7 to increase beam brightness; increased operating current from 100 mA to 200 mA to increase beam intensity; and maintained 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 were replaced in order to implement the revised lattice system. All components are housed within the existing buildings. The TEC was $29,000,000; DOE and NIH equally funded the upgrade with a total Federal cost of $58,000,000. NIH provided $14,000,000 in FY 1999, $14,000,000 in FY 2000, and $1,000,000 in FY 2001.

▪ **Advanced Light Source Beamline**	**975**	**0**	**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 was funded jointly by the Materials Sciences and Engineering subprogram and the Chemical Sciences, Geosciences, and Energy Biosciences subprogram.

	FY 2002	FY 2003	FY 2004
(dollars in thousands)			
▪ **The Center for Nanophase Materials**	**0**	**0**	**10,000**

Funds are provided for a major item of equipment with a total estimated cost of $36,000,000 for instrumentation, including clean rooms, for the Center for Nanophase Materials at Argonne National Laboratory. The instrumentation will be contained in a new building, which is being constructed by the State of Illinois for the Center at a cost of $36,000,000 and which will be dedicated to the Center operations. The building will be appended to the Advanced Photon Source. Included within the Center's instrument suite will be an x-ray nanoprobe beamline at the Advanced Photon Source. This beamline will be the highest spatial resolution instrument of its kind in the world, which will permit nondestructive examination of magnetic, electronic, and photonic materials important both for basic science and as foundations for future nanotechnologies. The Center will build on ANL's recognized strengths in magnetism, superconductivity, and novel materials with "spintronic" functionality.

	FY 2002	FY 2003	FY 2004
Facilities Operations	**268,032**	**274,118**	**290,004**
▪ **Operation of National User Facilities**	**268,032**	**274,118**	**290,004**

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.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Facilities			
Advanced Light Source	37,674	39,561	40,917
Advanced Photon Source	88,880	91,291	94,500
National Synchrotron Light Source	34,611	35,893	37,250
Stanford Synchrotron Radiation Laboratory	21,594	22,673	26,400
High Flux Isotope Reactor	38,697	36,854	38,357
Radiochemical Engineering Development Center	6,606	6,712	6,712
Intense Pulsed Neutron Source	15,826	17,015	17,200
Manuel Lujan, Jr. Neutron Scattering Center	9,044	9,678	10,271
Spallation Neutron Source	15,100	14,441	18,397
Total, Facilities	268,032	274,118	290,004

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
SBIR/STTR	**0**	**12,737**	**13,948**

In FY 2002, $14,363,000 and $862,000 were transferred to the SBIR and STTR programs, respectively. The FY 2003 and FY 2004 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.

Total, Materials Sciences and Engineering	**500,033**	**547,577**	**567,711**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Materials Sciences and Engineering Research	
▪ Increase for structure and composition of materials research for the design of components for an aberration corrected transmission electron microscope	+255
▪ Decrease in mechanical behavior and radiation effects research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-20
▪ Decrease in physical behavior of materials research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%	-22
▪ Decrease in synthesis and processing science research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-25

	FY 2004 vs. FY 2003 ($000)
▪ Decrease in engineering research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-23
▪ Decrease in condensed matter physics research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-52
▪ Decrease in condensed matter theory research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-25
▪ Decrease in materials chemistry research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-39
▪ Decrease in experimental program to stimulate competitive research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-12
▪ Increase for research and development for the Linac Coherent Light Source.	+2,000
▪ Increase for MIE for the ANL Center for Nanophase Materials	+10,000
▪ Increase for other project costs per schedule associated with the Nanoscale Science Research Centers	+300
▪ Decrease due to completion of the SPEAR3 Upgrade	-9,300
Total, Materials Sciences and Engineering Research	+3,037
Facilities Operations	
▪ Increase for operations for the Advanced Light Source.	+1,356
▪ Increase for operations for the Advanced Photon Source.	+3,209
▪ Increase for operations for the National Synchrotron Light Source	+1,357
▪ Increase for operations for the Stanford Synchrotron Radiation Laboratory.	+3,727
▪ Increase for operations for the High-Flux Isotope Reactor	+1,503
▪ Increase for operations for the Intense Pulsed Neutron Source.	+185
▪ Increase for operations for the Manuel Lujan, Jr. Neutron Scattering Center	+593
▪ Increase in the Spallation Neutron Source Other Project Costs per FY 2004 project datasheet	+3,956
Total, Materials Sciences and Engineering Facilities Operations.	+15,886
SBIR/STTR	
▪ Increase in SBIR/STTR funding because of an increase in operating expenses and an increase in STTR percentage from .15% to .3%	+1,211
Total Funding Change, Materials Sciences and Engineering	+20,134

Chemical Sciences, Geosciences, and Energy Biosciences

Mission Supporting Goals and Measures

Support is provided in the broad chemical sciences for 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.

In geosciences, support is provided for 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. This work 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.

In the area of bioscience, support is provided for 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.

Selected FY 2002 Research Accomplishments:

- *Catalytic Chemistry of Gold Nanoparticles.* Gold spheres of 2.7 nm diameter supported on titanium oxide are able to oxidize carbon monoxide, and spheres of 2.4 nm diameter are able to activate oxygen from air and insert it into propene readily and very selectively. Yet bulk gold metal is inert, and particles of slightly smaller or larger diameter than those cited are also unreactive or unselective. Using a variety of spectroscopic and chemisorption techniques, atomic-resolution microscopy, and theoretical electronic structure calculations, it was shown that decreasing metal particle size provokes changes in the electronic structures of gold and titanium oxide such that the particles are able to acquire a partial charge. Those variations are shown to decrease the binding energy of gold on titanium oxide (and thus alter the morphology of the clusters), as well as increase the binding energy of reactants such as oxygen, carbon monoxide, and propene to gold. The results explain why gold clusters are active and selective oxidation catalysts and provide a semiquantitative framework to predict catalytic reactivity on the basis of electronic structure of metal clusters.

- *New Nanoporous Catalysts Developed.* Nanocrystalline materials possess unique properties and offer great promise for promoting selected physical and chemical processes. Crystalline films of magnesium oxide that consist of tilted arrays of filaments attached to a flat substrate have been synthesized by impinging a magnesium atom beam in an oxygen background toward a surface off-normal by 70° to 85°. The individual filaments are thermally stable, highly ordered and porous, and contain enormous numbers of binding sites in comparison to a magnesium oxide flat surface deposited on a substrate. The high surface area (~1,000 m^2/g) and high density of binding sites potentially render these nanoporous materials extraordinary catalysts.
- *Multidimensional Catalyst Arrays.* Studies of the affects of particle spacing on the reactivity of catalysts has been hampered by the inability to produce uniform nanoparticles that are regularly distributed in a supporting matrix. Recent work shows that two- and three-dimensional arrays of platinum nanoparticles are achievable. Two-dimensional arrays of platinum supported on 4-inch silicon wafers were produced using electron beam lithography and spacer photolithography. The latter technique permits variation of particle size from 600 nm to 10 nm. More recently, three-dimensional arrays of 2-5 nm platinum nanoparticles of vary narrow size distribution were prepared, and the resulting x-ray and electron diffraction patterns are typical of crystallinity, hence regularity. The results significantly enhance enable the production of designer catalysts and will answer fundamental questions in catalysis.
- *Nanostructured Anodes.* There is considerable interest in tin/lithium anodes for high-energy electrochemical storage systems because, in principle, they can deliver substantially more storage capacity than carbon based lithium ion batteries. However, the tin-based anode functions by reversibly alloying lithium into the tin, and a very large volume expansion occurs when lithium is alloyed (as much as 300 percent). As a result, the tin based anode system typically has poor cycle life because the volume expansion and contraction during cycling causes the anode to self-destruct. New research has shown that nanostructured tin/lithium anodes prepared via a membrane template method do not suffer from this loss of cycle life, even after 1,400 charge discharge cycles. The nanostructured electrode gives good cycle life because the absolute volume change for a nanofiber is correspondingly small and because the brush like configuration of nanofibers provides room to accommodate the volume expansion.
- *Nanometer-Scale Faceting of Metals, a Means to Control Reactivity.* Bimetallic catalysts are providing new insights into chemical reactivity. Upon annealing at elevated temperatures, the atomically rough, "unstable" surfaces were observed to undergo massive reconstruction at the nanometer scale, in some instances leading to the formation of surface alloys. These structural rearrangements were accompanied by corresponding changes in electronic structure, morphology, and catalytic activity. Time-dependent, atomically resolved images allowed the measurement of the rate of facet growth and of their reconstruction in the presence of adsorbates such as sulfur and oxygen. Catalytic activity was found to dramatically depend on the composition, structure, size, and shape of the facets exposed under reaction conditions.

- *Organic Semiconductors.* Molecular and polymeric semiconductors are very important organic compounds that have the potential to replace inorganic semiconductors for applications in photoelectrochemical and photovoltaic cells for solar energy conversion of sunlight to electricity and solar fuels (hydrogen, methane, and alcohols). Photoconversion devices based on organic semiconductors could be much less expensive and easier to produce and process because of the present vast technology available for polymer and molecular processing into continuous thin films and sheets. Doping the molecular semiconductors to produce the required n-type and p-type electrical conductivity to create p-n junctions has been problematic as the dopant has not become part of the molecular or atomic structure of the compound. Recently, scientists successfully doped molecular semiconductors and increased the conductivity by five orders of magnitude.
- *Long-Lived Charge Separation in a Novel Artificial Photosynthetic Reaction Center.* Fullerenes and porphyrins have molecular architectures that are ideally suited for photochemical conversion and storage of solar energy. Their use as three-dimensional electron acceptors holds great promise because of their small reorganization energy in electron transfer reactions that can significantly improve light-induced charge-separation processes. Recent research indicated a 24 percent efficient charge-separation within a molecular tetrad. In this linear array, a light harvesting antenna assembly composed of two porphyrins and a fullerene-ferrocene photosynthetic reaction-center mimic were integrated into a single molecule. The 380 millisecond lifetime of the spatially-separated and high energy radical pair, a product of sequential short-range energy and electron transfer reactions, enters a time domain that has never been achieved in an artificial reaction center.
- *New Technique for Detection of Impact Ionization in Semiconductors.* The thermodynamic conversion efficiency with which solar radiant energy can be converted to electricity or to stored chemical energy in solar-derived fuels is limited by the energy loss of high energy electrons and positive holes created by the absorption of high energy solar photons in the photoconversion device. The thermodynamic efficiency limit can be more than doubled if the high energy photons can be used to create additional photogenerated current through a process called impact ionization. For the first time, scientists have demonstrated a contactless, optical method to detect impact ionization in semiconductors useful for solar photoconversion. The method is based on femtosecond time-resolved visible pump-infrared probe spectroscopy, and can be used to study impact ionization in colloidal semiconductor quantum dots where electrical contact to the colloidal particles is not possible. Impact ionization in semiconductor quantum dots is expected to be greatly enhanced.
- *Gas-Phase Chemistry of Actinide Ions.* The studies of gas-phase reactions of ions provide important insights into fundamental chemistry. Such studies have previously been limited to transition metal ions and to thorium and uranium in the actinide series; however, recent work has expanded this approach to the radioactive actinides, which cannot easily be studied by conventional techniques. One type of reaction that has been particularly enlightening involves the metal- or metal-oxide-catalyzed removal of hydrogen from alkene hydrocarbons. In these alkene dehydrogenation reactions, the neptunium ion is highly reactive, the plutonium ion is significantly less reactive, and the americium ion is essentially unreactive. This provides clear evidence that the 5f electrons of the actinides beyond neptunium are inert in these organometallic reactions. Results for the actinide oxide ions have also been illuminating, revealing a decrease in reactivity between uranium oxide ions and heavier actinide-oxide ions. The role of 5f electrons in bonding is central issue in contemporary actinide science, and these results provide experimental evidence for a change in the bonding nature

of the actinide 5f electrons in molecular compounds, ranging from being chemically active for the early members of the series to being inert for the actinides beyond neptunium.

- *Lattice Disorder and f-electrons: Evidence For a New State of Matter.* An important question is the nature of the non-superconducting high-temperature superconducting (HTSC) ground state from which superconductivity arises. Intermetallic alloys containing *f*-electron elements, in which superconductivity is absent or is easily suppressed, allow one to explore this question. Like HTSCs, *f*-electron intermetallic alloys often behave as "non-Fermi liquids" (NFL), so named because they are not consistent with Fermi liquid theory, which, until recently, has been the basis for explaining the properties of metals. Of specific interest is how the atoms surrounding an *f*-electron atom, and how disorder in their arrangement, affect magnetic and conducting properties. A recent study of these arrangements in the NFL compound UCu_4Pd showed that significant lattice disorder exists. Although such disorder can produce NFL behavior within a Fermi liquid model, the study showed that there is insufficient disorder for the model to match the measured magnetic and conductivity data. That is, the system acts as though it is more disordered than it actually is. These results strongly imply that lattice disorder precipitates NFL behavior in this material, perhaps by amplifying the effect of the disorder, and thereby the possibility of a new type of metallic ground state.
- *Cellulose Biosynthesis.* The detection and isolation of cellulose synthase genes is driving new efforts to understand how cellulose acquires its structural characteristics in hopes of eventually devising methods of tailoring these characteristics to facilitate its use as a renewable resource. Scientists have provided a key piece of information in the biochemical dissection of the three steps of cellulose synthesis: 1) initiation of the sugar chain; 2) adding sugars to the growing chain; and 3) stopping the process at a predetermined length. A single copy of a cellulose synthase gene was introduced into yeast cells that do not normally make cellulose. The result was the formation of a specific lipid-sugar compound that serves as a primer for subsequent chain growth. Understanding the critical steps in the synthesis of cellulose, the most abundant biomolecule, will lead to understanding the function of plant cell walls and to engineering modified renewable resources.
- *Boron in Plant Cell Walls.* Research has confirmed the role of the element boron in the growth and development of plant cell walls. Over 90 percent of a plant's boron is associated with the cell wall, and boron deficiency leads to stunted plants with malformed and brittle leaves. Arabidopsis thaliana mutants with a small change in the structure of a major type of cell wall carbohydrate show the same characteristics but can be rescued by feeding with excess borate. This defect was shown to reduce the plant's ability to bind the borate that is needed to form and stabilize the cross-linked cell wall. Future mechanistic studies relating borate-carbohydrate crosslinking to physiological growth could lead to improved strategies for the development and production of renewable biomass resources.
- *Naturally Occurring Organochlorine Compounds.* Organochlorine molecules are commonly observed in natural soils and have been attributed to pollution from manmade sources. Natural organic matter, such as humic and fulvic acid, in the shallow subsurface is both universal and little understood. It has no fixed stoichiometry or structure, cannot be crystallized, and is famously difficult to characterize reproducibly. Synchrotron x-ray spectroscopy has been used to document changes in the chemical state of chlorine in humic materials. This research confirmed the startling conclusion that natural organochlorine compounds are common in soil and that there is a net transfer of chlorine from inorganic to organic forms with common weathering. Abundant catalytic

peroxidase facilitates the chlorination of natural aromatic organics. These results add strong support to the hypothesis that chlorination of organic compounds in humic materials is widespread, and may explain the puzzling organochlorine concentrations found in otherwise unpolluted environments. Accurately understanding natural conditions is critical in identifying and taking action to correct man-made problems.

- *Quantum Degenerate Fermi Gases.* A new theoretical formulation predicts an unusually high critical temperature for the onset of superfluidity in a gas of fermionic potassium atoms. This new form of quantum matter, which lies between high-temperature superconductors and systems that undergo Bose-Einstein condensation should soon be achievable experimentally using optical traps. The ultimate goal of these experiments is to achieve Cooper pairing, in which pairs of fermionic atoms "condense" and occupy the lowest quantum states available to the ensemble of trapped atoms. Such an accomplishment would permit studies of the underlying mechanism of superconductivity.

Selected FY 2002 Facility Accomplishments:

- The Combustion Research Facility
  - *Stagnation-flow Reactor Designed to Probe High-temperature Chemistry.* Chemically reacting flows at interfaces are an important class of processes occurring in combustion, catalysis, thin film formation, and materials synthesis. An innovative stagnation-flow reactor with access for optical diagnostics and mass spectrometry is nearing completion and will provide a valuable tool for probing high-temperature chemistry for a broad range of industrially relevant processes.
  - *Fiber-based Laser Systems Developed.* Fiber lasers and amplifiers are unique optical sources that provide many advantages for detection of chemical and biological compounds. The CRF has established the capability to fabricate them in-house. The facility will allow the pursuit of new research in optical diagnostics and will help DOE remain at the forefront of this field.
  - *New Reactor Allows Investigation of Gasification Processes.* The design and facility modifications have been completed for a new reactor that will allow unprecedented optical access to pressurized combustion and gasification processes. This reactor will give the CRF the capability to investigate gas-phase kinetics, materials behavior, advanced diagnostic development, and solid and liquid fuel combustion chemistry and physics under pressurized conditions.

Subprogram Goals

Build leading research programs in chemical sciences, geosciences, and energy biosciences and provide world-class, peer-reviewed research results cognizant of DOE needs as well as the needs of the broad scientific community.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Validation of program directions by Basic Energy Sciences Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
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, the chemical sciences activities in BES were reviewed using a Basic Energy Sciences Advisory Committee - chartered Committee of Visitors. [Met Goal]		
Conducted workshop on research opportunities and needs related to electron initiated chemistry in aqueous media. [Met Goal]		
	Sponsor a workshop on plant systems science to identify opportunities and challenges associated with the molecular level understanding of plant processes. Specifically identify opportunities at the interfaces among the biological, physical, mathematical, and computational sciences.	Implement workshop recommendations in the area of plant systems science.
		Evaluate the following ongoing efforts using Basic Energy Sciences research workshops with the goal of directing the activities toward international leadership and relevance to emerging technologies: chemical physics and fundamental chemical interactions. Publish results and continue to structure BES programs per results.
		Implement recommendations and new program directions in chemical sciences, geosciences, and biosciences that resulted from the BESAC-chartered workshop on "Basic Research Needs to Assure a Secure Energy Future."

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.

Performance Indicators

Validation of results by merit review with external peer evaluation.

Validation of program directions by Basic Energy Sciences Advisory Committee.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
Conducted a joint BESAC- and ASCAC-sponsored Workshop on Theory and Modeling in Nanoscience (May 10-11, 2002) to identify opportunities and challenges in theory, modeling and simulation that can accelerate discovery and understanding at the nanoscale. [Met Goal]		
Conducted a BESAC-chartered workshop on Catalysis (May 14-16, 2002) [Met Goal]	Implement the recommendations of the Catalysis workshop by initiating multi-disciplinary, multi-institution research efforts in catalysis enabled by emerging nanoscience technologies including biosciences.	Continue implementation of the recommendations of the Catalysis workshop with continuing emphasis on multi-disciplinary approaches.
In FY 2002, there were 19 new grants awarded to universities and 6 projects at DOE laboratories were initiated in selected chemical sciences, geosciences, and energy biosciences areas of nanoscale science, engineering, and technology. [Met Goal]		

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Chemical Sciences, Geosciences, and Energy Biosciences Research	194,850	209,188	209,597	+409	+0.2%
Facilities Operations	5,377	5,805	5,967	+162	+2.8%
SBIR/STTR	0	5,022	5,350	+328	+6.5%
Total, Chemical Sciences, Geosciences, and Energy Biosciences	200,227	220,015	220,914	+899	+0.4%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Chemical Sciences, Geosciences, and Energy Biosciences Research	**194,850**	**209,188**	**209,597**
▪ **Atomic, Molecular, and Optical (AMO) Science**	**11,815**	**11,815**	**12,275**

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 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.

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.

In FY 2004, major activities will 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.

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 2002	FY 2003	FY 2004
▪ **Chemical Physics Research**	**33,285**	**33,285**	**33,239**

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 characteristic of combustion with the aim of developing theories and computational tools 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.

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

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 Fossil Energy and 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. Predicted and measured reaction rates will be 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.

The SciDAC computational chemistry program addresses three fundamental research efforts: chemically reacting flows, the chemistry of unstable species and large molecules, and actinide chemistry. Each of these research efforts is carried out by a team of related scientists working with the appropriate Integrated Software Infrastructure Centers supported under SciDAC by the SC Advanced Scientific Computing Research program.

Capital equipment is provided for such items as picosecond and femtosecond lasers, high-speed detectors, spectrometers and computational resources.

	FY 2002	FY 2003	FY 2004
▪ **Photochemistry and Radiation Research**	**26,096**	**29,032**	**28,973**

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 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.

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 Nuclear Energy Research Initiative (NERI) and the Environmental Molecular Science Program (EMSP) projects.

This activity is the dominant supporter (85%) of solar photochemistry in the U.S., and the sole supporter of radiation chemistry.

In FY 2004, major activities will include research 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; 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.

	FY 2002	FY 2003	FY 2004
▪ **Molecular Mechanisms of Natural Solar Energy Conversion**	**12,060**	**12,150**	**12,133**

This activity 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.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
▪ **Metabolic Regulation of Energy Production**	**19,130**	**19,224**	**19,195**

This activity 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 2004, 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.

▪ **Catalysis and Chemical Transformation**..................................	**24,779**	**31,333**	**32,333**

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. 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. The production of virtually every chemical-based consumer product requires catalysts. Catalysts are crucial to energy conservation in creating new, less-energy-demanding routes for the production of basic chemical feedstocks and value-added chemicals. 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.

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

In FY 2004, the activity will continue to address recommendations of the FY 2002 BESAC-sponsored workshop that described new opportunities afforded by progress in the tools and concepts of nanoscience. The availability of new tools for preparation, characterization, and analysis and the merging of concepts drawn from homogeneous (single phase such as solution) catalysis, heterogeneous (between phases such as gas-surface) catalysis, and biocatalysts provide the potential to pioneer new approaches to catalysis design. Recommendations of the workshop include the use of multidisciplinary approaches involving the establishment of competitively selected centers of excellence that provide access to special research facilities especially state-of-the-art microscopes, light sources, neutron sources, terascale computers, and/or nanoscience centers in order to capitalize on their unique capabilities.

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 2002	FY 2003	FY 2004
▪ **Separations and Analyses**	**12,967**	**14,407**	**14,387**

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; 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 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.

In FY 2004, major activities will include studies in at the nanoscale as well as the formation of macroscopic separation systems via self-assembly of nanoscale precursors. This work will build on recent advances in imaging single-molecule interactions and reactions and will expand our knowledge

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

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.

	FY 2002	FY 2003	FY 2004
▪ **Heavy Element Chemistry**	**7,637**	**8,637**	**8,625**

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.

In FY 2004, major activities will include experiment, theory, and modeling to understand the chemical bonding in the heavy 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.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

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.

▪ **Geosciences Research**	**21,252**	**21,262**	**21,232**

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. 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.

▪ **Chemical Energy and Chemical Engineering**	**10,953**	**10,953**	**10,937**

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.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

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 Energy Efficiency and Renewable Energy's Transportation Technologies program is accomplished through joint program meetings, workshops, and strategy sessions.

In FY 2004, major activities will include 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.

	FY 2002	FY 2003	FY 2004
▪ **General Plant Projects (GPP)**..	**10,265**	**12,210**	**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.

	FY 2002	FY 2003	FY 2004
▪ **General Purpose Equipment (GPE)**	**2,936**	**4,180**	**4,058**

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.

	FY 2002	FY 2003	FY 2004
▪ **SPEAR3 Upgrade**	**700**	**700**	**0**

Over the period FY 1999 - FY 2003, the SPEAR3 upgrade (funded in both BES subprograms) was undertaken at SSRL to provide major improvements to all existing experimental stations served by this synchrotron radiation light source. The upgrade increased injection energy from 2.3 GeV to 3 GeV to improve the energy spectrum available to users; decreased beam emittance by a factor of 7 to increase beam brightness; increased operating current from 100 mA to 200 mA to increase beam intensity; and maintained 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

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

were replaced in order to implement the revised lattice system. All components are housed within the existing buildings. The TEC was $29,000,000; DOE and NIH equally funded the upgrade with a total Federal cost of $58,000,000. NIH provided $14,000,000 in FY 1999, $14,000,000 in FY 2000, and $1,000,000 in FY 2001.

▪ **Advanced Light Source Beamline**..	**975**	**0**	**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.

Facility Operations...	**5,377**	**5,805**	**5,967**

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 2002	FY 2003	FY 2004
Facilities			
Combustion Research Facility	5,377	5,805	5,967
Total, Facilities	5,377	5,805	5,967

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
SBIR/STTR..	**0**	**5,022**	**5,350**

In FY 2002 $1,309,000 and $78,000 were transferred to the SBIR and STTR programs, respectively. The FY 2003 and FY 2004 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.

Total, Chemical Sciences, Geosciences, and Energy Biosciences.	**200,227**	**220,015**	**220,914**

Explanation of Funding Changes from FY 2003 to FY 2004

	FY 2004 vs. FY 2003 ($000)
Chemical Sciences, Geosciences, and Energy Biosciences Research	
▪ Increase in atomic, molecular, and optical science to advance ultrafast science through the application of new x-ray sources, including short wave length high power light sources.	+460
▪ Decrease in chemical physics research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-46
▪ Decrease in photochemistry and radiation research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-59
▪ Decrease in molecular mechanisms of natural solar energy conversion research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-17
▪ Decrease in metabolic regulation of energy production research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-29
▪ Increase in catalysis research to understand the role nanoscale properties play in altering and controlling catalytic transformations.	+1,000
▪ Decrease in separations and analyses research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-20
▪ Decrease in heavy element chemistry research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-12
▪ Decrease in geosciences research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-30
▪ Decrease in chemical energy and chemical engineering research due to increase in FY 2004 for STTR. The percentage increases from .15% to .3%.	-16
▪ Decrease in general purpose equipment.	-122
▪ Decrease due to completion of SPEAR3 Upgrade	-700
Total, Chemical Sciences, Geosciences, and Energy Biosciences Research	+409
Facilities Operations	
▪ Increase for operations of the Combustion Research Facility.	+162
Total, Chemical Sciences, Geosciences, and Energy Biosciences Facilities Operations	+162

	FY 2004 vs. FY 2003 ($000)
SBIR/STTR	
▪ Increase SBIR/STTR funding because of an increase in operating expenses and an increase in STTR percentage from .15% to .3%.	+328
Total Funding Change, Chemical Sciences, Geosciences, and Energy Biosciences	+899

Construction

Mission Supporting Goals and Measures

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 2002	FY 2003	FY 2004	$ Change	% Change
SNS	276,300	210,571	124,600	-85,971	-40.8%
Project Engineering Design, NSRCs	3,000	11,000	3,000	-8,000	-72.7%
Project Engineering Design, LCLS	0	6,000	7,500	+1,500	+25.0%
Center for Nanophase Materials Science (ORNL)	0	24,000	20,000	-4,000	-16.7%
The Molecular Foundry (LBNL)	0	0	35,000	+35,000	--
Center for Integrated Nanotechnologies (SNL/LANL)	0	0	29,850	+29,850	--
Total, Construction	279,300	251,571	219,950	-31,621	-12.6%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Construction	**279,300**	**251,571**	**219,950**
Spallation Neutron Source	**276,300**	**210,571**	**124,600**

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.

(dollars in thousands)

FY 2002	FY 2003	FY 2004

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.

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. In addition to these two instruments, in FY 2003 and FY 2004, 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.

Funds appropriated in FY 2002 continued R&D, design, procurement, construction activities, and component installation. Essentially all R&D supporting construction of the SNS was completed, with instrument R&D continuing. Title II design was completed on the linac and was continued on the ring, target, and instrument systems. The completed ion source and portions of the drift tube linac were delivered to the site and their installation was begun. Other system components for the accelerator, ring, target, and instruments continued to be manufactured. Work on conventional facilities continued, with some reaching completion and being turned over for equipment installation, such as the ion source building and portions of the klystron building and linac tunnel. Construction work began 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 ion source 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.

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

FY 2004 budget authority is requested to continue instrument R&D, design, and procurement. The drift-tube linac and cavity-coupled linac portions of the warm linac commissioning will be completed. Other commissioning activities will continue in the linac. Cryogenic refrigerator installation and system cool down will be completed and cryogenic transfer line installation and testing will be completed. Cryogenic module fabrication and installation will continue. High-energy beam transport installation and testing will be completed. Ring fabrication and assembly activities will continue. Target fabrication and assembly activities will continue. Most SNS buildings will be completed with the exception of ongoing construction work in the target and instrument facilities and the central laboratory and office building.

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. Additional information on the SNS Project is provided in the SNS construction project data sheet, project number 99-E-334.

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.

	FY 2002	FY 2003	FY 2004
Project Engineering and Design, Nanoscale Science Research Centers	**3,000**	**11,000**	**3,000**

FY 2002 and 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 Laboratories (Albuquerque). *FY 2004 budget authority is requested for a NSRC at Brookhaven National Laboratory. These funds will be used to assure project feasibility, define the scope, and provide estimates of construction costs and schedules. NSRCs 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.

	FY 2002	FY 2003	FY 2004
Project Engineering and Design, Linac Coherent Light Source..	**0**	**6,000**	**7,500**

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 billion times 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 billion times 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 $200,000,000 to $240,000,000. FY 2004 Project Engineering Design (PED) funding of $7,500,000 and $2,000,000 of research and development are 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.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Nanoscale Science Research Center – The Center for Nanophase Materials Sciences, ORNL	**0**	**24,000**	**20,000**

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. FY 2004 funding is requested to continue this construction. **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.

Nanoscale Science Research Center – The Molecular Foundry, LBNL	**0**	**0**	**35,000**

FY 2004 funding is requested for the start of construction of the Molecular Foundry at Lawrence Berkeley 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 04-R-313.

Nanoscale Science Research Center – The Center for Integrated Nanotechnologies, Sandia National Laboratories/Los Alamos National Laboratory	**0**	**0**	**29,850**

FY 2004 funding is requested for the start of construction of the Center for Integrated Nanotechnologies managed jointly by Sandia National Laboratories and Los Alamos 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 04-R-314.

Total, Construction	**279,300**	**251,571**	**219,950**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Construction	
▪ Decrease in funding for the Spallation Neutron Source, representing the scheduled ramp down of activities.	-85,971
▪ Decrease in Project Engineering and Design for Nanoscale Science Research Centers at ORNL, LBNL, SNL, and BNL.	-8,000

	FY 2004 vs. FY 2003 ($000)
▪ Increase in funding for Project Engineering Design related to design-only activities for the Linac Coherent Light Source (LCLS) to be located at the Stanford Linear Accelerator Center (SLAC).	+1,500
▪ Decrease in funding for construction of the Center for Nanophase Materials Sciences to be located at ORNL, representing the scheduled ramp down of activities	-4,000
▪ Increase in funding for construction of the Molecular Foundry to be located at LBNL, representing the start of construction.	+35,000
▪ Increase in funding for construction of the Center for Integrated Nanotechnologies, to be located at SNL, representing the start of construction.	+29,850
Total Funding Change, Construction	-31,621

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 2002	FY 2003	FY 2004	$ Change	% Change
Advanced Light Source	37,674	39,561	40,917	+1,356	+3.4%
Advanced Photon Source	88,880	91,291	94,500	+3,209	+3.5%
National Synchrotron Light Source	34,611	35,893	37,250	+1,357	+3.8%
Stanford Synchrotron Radiation Laboratory	21,594	22,673	26,400	+3,727	+16.4%
High Flux Isotope Reactor	38,697	36,854	38,357	+1,503	+4.1%
Radiochemical Engineering Development Center	6,606	6,712	6,712	0	--
Intense Pulsed Neutron Source	15,826	17,015	17,200	+185	+1.1%
Manuel Lujan, Jr. Neutron Scattering Center	9,044	9,678	10,271	+593	+6.1%
Spallation Neutron Source	15,100	14,441	18,397	+3,956	+27.4%
Combustion Research Facility	5,377	5,805	5,967	+162	+2.8%
Total, Major User Facilities	273,409	279,923	295,971	+16,048	+5.7%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Major User Facilities	**273,409**	**279,923**	**295,971**
▪ Advanced Light Source at Lawrence Berkeley National Laboratory	37,674	39,561	40,917
▪ Advanced Photon Source at Argonne National Laboratory.	88,880	91,291	94,500
▪ National Synchrotron Light Source at Brookhaven National Laboratory	34,611	35,893	37,250
▪ Stanford Synchrotron Radiation Laboratory at Stanford Linear Accelerator Center.	21,594	22,673	26,400
▪ High Flux Isotope Reactor at Oak Ridge National Laboratory.	38,697	36,854	38,357
▪ Radiochemical Engineering Development Center (REDC) at Oak Ridge National Laboratory.	6,606	6,712	6,712
▪ Intense Pulsed Neutron Source at Argonne National Laboratory.	15,826	17,015	17,200
▪ Manuel Lujan, Jr. Neutron Scattering Center at Los Alamos National Laboratory.	9,044	9,678	10,271
▪ Spallation Neutron Source at Oak Ridge National Laboratory.	15,100	14,441	18,397
▪ Combustion Research Facility at Sandia National Laboratories/California.	5,377	5,805	5,967
Total, Major User Facilities	273,409	279,923	295,971

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
General Plant Projects	10,613	12,570	12,618	+48	+0.4%
Accelerator Improvement Projects	11,292	9,067	9,440	+373	+4.1%
Capital Equipment	62,437	76,249	77,328	+1,079	+1.4%
Total, Capital Operating Expenses	84,342	97,886	99,386	+1,500	+1.5%

Construction Projects

	(dollars in thousands)					
	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2002	FY 2003	FY 2004	Unapprop-riated Balances
99-E-334, ORNL, Spallation Neutron Source	1,192,700	460,329	276,300	210,571	124,600	120,900
02-SC-002 PED, Nanoscale Science Research Centers	20,000 [a]	0	3,000	11,000	3,000	3,000
03-SC-002, PED, SLAC, Linac Coherent Light Source	36,000 [b]	0	0	6,000	7,500	22,500
03-R-312, ORNL, Center for Nanophase Material Sciences	64,000 [c]	0	0	24,000	20,000	17,500
04-R-313, LBNL, The Molecular Foundry	83,700[d]	0	0	0	35,000	41,400
04-R-314, SNL, Center for Integrated Nanotechnologies	73,800[e]	0	0	0	29,850	39,750
Total, Construction		460,329	279,300	251,571	219,950	

[a] The full Total Estimated Cost (design and construction) ranges between $286,500,000,000 and $306,500,000. 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 $200,000,000 and $240,000,000. This is a preliminary estimate based on conceptual design and should not be construed as a project baseline.

[c] Includes $2,500,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.

[d] Includes $7,300,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.

[e] Includes $4,200,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2002	FY 2003	FY 2004	Accept-ance Date
SPEAR3 Upgrade	29,000[a]	10,000	9,000	10,000	0	FY 2004
ALS Beamline	6,000	4,050	1,950	0	0	FY 2003
ANL Center for Nanophase Materials	36,000	0	0	0	10,000	FY 2006
Total, Major Items of Equipment		14,050	10,950	10,000	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 2003 Congressional Budget Request are denoted with a vertical line in the left margin.)

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 1999 Budget Request (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	1Q 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	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700
FY 2004 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	253,059
2003	210,571	210,571	322,277
2004	124,600	124,600	176,690
2005	79,800	79,800	73,065
2006	41,100	41,100	54,474

[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. In order to efficiently fund certain work related to this instrument that must uniquely be performed by the SNS project (e.g., design and procurement of target interfacing components, technical coordination, instrument installation), DOE will be providing about 20 percent of the above grant amount directly to Oak Ridge National Laboratory and the grant will be reduced accordingly.

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. As with the above instrument grant and for the same reasons, DOE will be providing about 20 percent of the grant amount directly to Oak Ridge National Laboratory and the grant will be reduced accordingly.

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 and FY 2004 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, and biological 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 fully 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.

The scientific justification and need for a new neutron source and instrumentation in the U.S. were established by numerous studies by the scientific community since the 1970s. These include the 1984 National Research Council study *Major Facilities for Materials Research and Related Disciplines* (the Seitz-Eastman Report), which recommended the immediate start of the design of both a steady-state source and an accelerator-based pulsed spallation source. More recently, the 1993 DOE Basic Energy Sciences Advisory Committee (BESAC) report *Neutron Sources for America's Future* (the Kohn Panel Report) again included construction of a new pulsed spallation source with SNS capabilities among its highest priorities. This conclusion was even more strongly reaffirmed by the 1996 BESAC Report (the Russell Panel Report), which recommended the construction of a 1 megawatt (MW) spallation source that could be upgraded to significantly higher powers in the future.

Neutron scattering enables the determination of the positions and motions of atoms in materials, and it has become an increasingly indispensable scientific tool. Over the past decade, it has 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. The information that neutron scattering provides has wide impacts. For example, chemical companies use neutrons to make better fibers, plastics, and catalysts; drug companies use neutrons to design drugs with higher potency and fewer side effects; and automobile manufacturers use the penetrating power of neutrons to understand how to cast and forge gears and brake discs in order to make cars run better and more safely. Furthermore, research on magnetism using neutrons has led to higher strength magnets for more efficient electric generators and motors and to better magnetic materials for magnetic recording tapes and computer hard drives.

Based on the recommendations of the scientific community obtained via the Russell Panel Report, the SNS 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.

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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.

The importance of high power – and consequently 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 neutron intensity enables studies of small samples, complex molecules and structures, time-dependent phenomena, and very weak interactions.

The SNS will consist of a linac-ring accelerator system that delivers short (microsecond) pulses to a target/moderator system where neutrons are produced by a 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 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. 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.

Funds appropriated in FY 2002 continue R&D, design, procurement, construction activities, and component installation. Essentially all R&D supporting construction of the SNS was completed, with instrument R&D continuing. Title II design was completed on the linac, and continued on the ring, target, and instrument systems. The completed ion source and portions of the drift tube linac were delivered to the site and their installation was begun. Other system components for the accelerator, ring, target, and instruments continued to be manufactured. Work on conventional facilities continued, 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 began 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 ion source 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.

FY 2004 budget authority is requested to continue instrument R&D, design, and procurement. The drift tube linac and coupled cavity linac subsystems will be commissioned. Other commissioning activities will continue in the linac. Cryogenic refrigerator installation and system cool down will be completed, and cryogenic transfer line installation and testing will be completed. Cryogenic module fabrication and installation will continue. The high-energy beam transport installation and testing will be completed. Ring fabrication and assembly activities will continue. Target fabrication and assembly activities will continue. Most buildings will be completed with the exception of ongoing construction work in the target building and the central laboratory and office building.

4. Details of Cost Estimate [1]

	(dollars in thousands) Current Estimate	Previous Estimate
Design and Management Costs		
Engineering, design and inspection at approximately 21% of construction costs	159,500	159,500
Construction management at approximately 2% of construction costs	14,000	14,000
Project management at approximately 14% of construction costs	104,700	104,700
Land and land rights	0	0
Construction Costs		
Improvements to land (grading, paving, landscaping, and sidewalks)	31,500	31,500
Buildings	196,300	181,600
Utilities (electrical, water, steam, and sewer lines)	20,900	20,900
Technical Components	507,200	505,500
Standard Equipment	17,500	17,500
Major computer items	5,500	5,500
Design and project liaison, testing, checkout and acceptance	31,000	31,000
Subtotal	1,088,100	1,071,700
Contingencies at approximately 10% of above costs [2]	104,600	121,000
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 project is using the appropriated funds included in the TEC to meet or exceed the project performance baseline. The project is also accepting transferred surplus materials and equipment to the extent possible. Examples of the transferred items include ring pumps, lead bricks, concrete blocks, trailers and furniture. The net book value of the surplus materials will be far less than one percent of the TEC over the life of the project. All such transferred materials will be appropriately recorded as non-fund cost and capitalized.

[2] 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 – Ion Source; 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 2002	FY 2003	FY 2004	Outyears	Total
Project Cost						
Facility Cost [1]						
Line Item TEC	313,135	253,059	322,277	176,690	127,539	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	313,135	253,059	322,277	176,690	127,539	1,192,700
Other project costs						
R&D necessary to complete project [2]	73,374	5,409	2,122	1,663	1,156	83,724
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	10	0	0	0	1,958
Other project-related costs [5]	10,531	10,165	13,048	17,376	66,698	117,818
Capital equipment not related construction [6]	847	-1	150	107	0	1,103
Total, Other project costs	101,097	15,583	15,320	19,146	67,854	219,000
Total project cost (TPC)	414,232	268,642	337,597	195,836	195,393	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 $83,724,000 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] Costs of $1,958,000 are included for completion of the Environmental Impact Statement.

[5] Estimated costs of $117,818,000 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)	
	Current Estimate	Previous Estimate
Facility operating costs	45,700	45,700
Facility maintenance and repair costs	24,800	24,800
Programmatic operating expenses directly related to the facility	40,000	40,000
Capital equipment not related to construction but related to the programmatic effort in the facility	11,800	11,800
GPP or other construction related to the programmatic effort in the facility	1,000	1,000
Utility costs	19,400	19,400
Accelerator Improvement Modifications (AIMs)	7,300	7,300
Total related annual funding (4Q FY 2006 will begin operations)	150,000	150,000

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.

02-SC-002 - Project Engineering Design (PED), Various Locations

(Changes from the FY 2003 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	2Q 2002	3Q 2003	N/A	N/A	15,000
FY 2004 Budget Request (Current Estimate)	2Q 2002	3Q 2003	N/A	N/A	20,000[a]

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	3,000	3,000	1,547
2003	11,000	11,000	11,163
2004	3,000	3,000	4,290
2005	3,000	3,000	3,000

3. Project Description, Justification and Scope

This PED request provides for Title I and Title II Architect-Engineering (A-E) services for 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.

[a] The full Total Estimated Cost (design and construction) ranges between $286,500,000 - $306,500,000. 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 increased to $20,000,000. The full Total Estimated Cost for each of the three currently proposed NSRC construction projects is identified in the FY 2004 construction datasheets.

Updated FY 2002 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 three of the FY 2002 subprojects is also separately requested in FY 2004.

<u>Nanoscale Science Research Centers (NSRCs)</u>

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 has been provided in FY 2002 and requested in FY 2003 for LBNL, ORNL, and LANL/SNL. Construction funding was also requested for ORNL in FY 2003. In FY 2004, PED funding is requested for BNL, while construction funds are requested for ORNL, LBNL, and LANL/SNL.

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 ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
N/A	N/A	N/A	N/A	0 [a]	0 [a]

Fiscal Year	Appropriations	Obligations	Costs
2002	0 [a]	0[a]	0[a]
2003	0 [a]	0[a]	0[a]

The Center for Nanoscale Materials (CNM) at ANL will consist of conventional facilities, fabrication facilities, characterization instruments, computational capabilities, and a beamline 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. The CNM is being coordinated with a State of Illinois effort. The State of Illinois is providing design and construction funding in FY 2002-2004 for the building. For this reason, PED funding is not planned or requested for this effort.

[a] 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 was not planned for FY 2002 or in the FY 2003 Request. The building portion of the project is being funded by the State of Illinois while DOE plans to fund capital equipment for the Center as one or more MIEs. The CNM is funded at $10,000,000 in FY 2004 President's Request with a MIE TEC of $36,000,000.

02-02: The Molecular Foundry – Lawrence Berkeley National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
3Q 2002	1Q 2004	2Q 2004	1Q 2007	7,300	83,700 [a]

Fiscal Year	Appropriations	Obligations	Costs
2002	500 [b]	500 [b]	38 [b]
2003	6,800 [b]	6,800 [b]	5,972 [b]
2004	0 [b]	0 [b]	1,290 [b]

The proposed Molecular Foundry at LBNL will be a new structure near the National Center for Electron Microscopy. The project includes an approximately 80,000 gross square foot research building, a separate approximately 5,000 gross square foot utility center, and special equipment to support nanoscale scientific research. The research building will be an advanced facility for the design, modeling, synthesis, processing, fabrication and characterization of novel molecules and nanoscale materials. Space in the new facility will support studies in nanostructures by providing offices and laboratories for materials science, physics, chemistry, biology, and molecular biology. These laboratories, equipped with advanced instrumentation and staffed by full-time, dedicated staff scientists and technicians, will be user facilities, available to scientists from universities, industry, and government laboratories whose research proposals have been peer reviewed by a Proposal Study Panel. This combination of advanced equipment, collaborative staff, and breadth across disciplines will allow users to explore the frontiers of nanoscience. 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 2003 Request included $500,000 for FY 2002, $6,800,000 for FY 2003, and $1,000,000 for FY 2004. The current funding plan eliminates the PED funding in FY 2004. The project is now proposed for construction in FY 2004.

02-03: Center for Functional Nanomaterials – Brookhaven National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
2Q 2004	3Q 2005	N/A	N/A	6,000	70,000-85,000 [a]

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	0 [b]	0 [b]	0 [b]
2003	0 [b]	0 [b]	0 [b]
2004	3,000 [b]	3,000 [b]	3,000 [b]
2005	3,000	3,000	3,000

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 an initial set of equipment necessary to explore, manipulate, and fabricate nanoscale materials and structures. Also included are individual offices, seminar area, transient user space for visiting collaborators with access to computer terminals, conference areas, and vending/lounge areas, 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 was not planned for FY 2002 or requested for this project in FY 2003. Based on the review of a revised proposal, PED funding is requested in FY 2004.

[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 was not planned for FY 2002 or in the FY 2003 Request. Based on the merits of a revised proposal, $3,000,000 of PED funding is requested in FY 2004.

02-04: Center for Nanophase Materials Sciences – Oak Ridge National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
2Q 2002	1Q 2003	3Q 2003	4Q 2006	2,500 [a]	64,000 [b]

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	1,500 [b]	1,500 [b]	1,342 [b]
2003	1,000 [b]	1,000 [b]	1,158 [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 building (approximately 80,000 gross square feet) will contain 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 a review, this project is proposed for construction funding in FY 2003.

[a] Funding of $1,000,000 in FY 2003 and $2,000,000 in FY 2004 was identified in the FY 2003 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.

[b] 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).

02-06: The Center for Integrated Nanotechnologies (CINT) – Sandia National Laboratories/Los Alamos National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
3Q 2002	2Q 2004	3Q 2004	3Q 2007	4,200	73,800 [a]

Fiscal Year	Appropriations	Obligations	Costs
2002	1,000 [b]	1,000 [b]	167 [b]
2003	3,200 [b]	3,200 [b]	4,033 [b]

The Center for Integrated Nanotechnologies (CINT), jointly managed by the Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL), 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 core research facility to be located in an unrestricted area just outside the restricted area at 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 core research facility and the gateways will be managed as one integrated facility by a single management structure led by SNL. 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 CINT core facility 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 an initial set of equipment for nanolithography, atomic layer deposition, and materials characterization along with general purpose chemistry and electronics labs and offices for Center staff and collaborators.

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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. CINT combines the projects identified 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 in 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 [1]

(dollars in thousands)

	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs (Design Drawings and Specifications)	15,000	11,250
Design Management costs (15% of TEC)	3,000	2,250
Project Management costs (10% of TEC)	2,000	1,500
Total Design Costs (100% of TEC)	20,000	15,000
Total, Line Item Costs (TEC)	20,000	15,000

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 2002	FY 2003	FY 2004	Outyears	Total
Facility Cost						
PED	0	1,547	11,163	4,290	3,000	20,000
Other project costs [2]						
Conceptual design cost	1,370	440	0	0	0	1,810
Total, Other Project Costs	1,370	440	0	0	0	1,810
Total, Project Costs	1,370	1,987	11,163	4,290	3,000	21,810

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[1] 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.

[2] Only Conceptual Design Costs associated with the NSRCs are included. Other project costs are identified for individual NSRCs on the individual construction project data sheets for Project 03-R-312, Center for Nanophase Materials Sciences; Project 04-R-313, Molecular Foundry; and Project 04-R-314, Center for Integrated Nanotechnologies.

03-SC-002, Project Engineering Design (PED), Linac Coherent Light Source, Stanford Linear Accelerator Center

(Changes from the FY 2003 Congressional Budget Request are denoted with a vertical line in the left margin.)

Significant Changes

The Total Estimated Cost has increased by $2,500,000 due to FY 2004 fiscal constraints that deferred some design work from FY 2004 to FY 2005.

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost[a] ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Project Complete	
FY 2003 Budget Request (Preliminary Estimate)	1Q 2003	2Q 2005	N/A	N/A	$33,500
FY 2004 Budget Request (Current Estimate)	1Q 2003	4Q 2006	N/A	N/A	$36,000

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2003	6,000	6,000	5,500
2004	7,500	7,500	7,000
2005	20,,000	20,000	21,000
2006	2,500	2,500	2,500

3. Project Description, Justification and Scope

These funds allow the Linac Coherent Light Source (LCLS), located at the Stanford Linear Accelerator Center (SLAC), 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, 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.

[a] The full TEC Projection (design and construction) ranges between $200,000,000 and $240,000,000. This is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

The purpose of the LCLS Project is to provide laser-like radiation in the x-ray region of the spectrum that is 10 billion times 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 be equally dramatic. The LCLS Project will provide the first demonstration of an x-ray free-electron-laser (FEL) in the 1.5 – 15 Angstrom 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 new 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 billion times 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 may make 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 entire 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. Two new experimental buildings, the Near Hall and the Far Hall will be constructed. They will be connected by the beam line tunnel, and the Far Hall will provide laboratory and office space for LCLS users.

4. Details of Cost Estimate[a]

(dollars in thousands)

	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs (Design Drawings and Specifications)	26,000	25,125
Design Management costs	5,000	5,025
Project Management costs	5,000	3,350
Total Design Costs	36,000	33,500
Total, Line Item Costs (TEC)	36,000	33,500

5. Method of Performance

A Conceptual Design Report (CDR) for the project has been completed and reviewed. 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).

[a] This cost estimate includes design phase activities only. Construction activities will be requested to be funded in FY 2005.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 2002	FY 2003	FY 2004	Outyears	Total
Facility Cost						
PED	0	0	5,500	7,000	23,500	36,000
Other project costs						
Conceptual design cost	0	1,500	0	0	0	1,500
Research and development costs	0	0	0	2,000	4,000	6,000
NEPA documentation costs	0	0	0	0	0	0
Other project related costs	0	0	0	0	0	0
Total, Other Project Costs	0	1,500	0	2,000	4,000	7,500
Total Project Cost (TPC)	0	1,500	5,500	9,000	27,500	43,500

03-R-312, Center For Nanophase Materials Sciences
Oak Ridge National Laboratory, Oak Ridge, Tennessee

(Changes from FY 2003 Congressional Budget Request are denoted with a vertical line in the left margin.)

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 2003 Budget Request (Preliminary Estimate)............................	2Q2002	1Q2003	3Q2003	4Q2006	$64,000	$65,000
FY 2004 Budget Request (Current 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]	1,342[a]
2003	1,000[a]	1,000[a]	1,158[a]
Construction			
2003	24,000[a]	24,000[a]	7,100[a]
2004	20,000	20,000	28,000
2005	17,500	17,500	19,700
2006	0	0	6,700

[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 beginning 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. 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, co-located 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 an initial set 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	1,700
Design and Project Management Costs	300	300
Total, Design Costs	2,000	2,000
Construction Phase		
Improvements to Land	500	500
Buildings	19,700	19,700
Special Equipment[2]	26,000	26,000
Utilities	500	500
Inspection, design and project liaison, testing, checkout and Acceptance	1,800	1,800
Construction and Project Management	1,700	1,700
Total, Construction Costs	50,200	50,200
Contingency (23.5% of Construction Costs)	11,800	11,800
Total, Line Item Costs (TEC)	64,000	64,000

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.

[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, including testing and acceptance.

6. Schedule of Project Funding

	Prior Years	FY 2002	FY 2003	FY 2004	Outyears	Total
Project Cost						
Facility Cost						
Design	0	1,342	1,158	0	0	2,500
Construction	0	0	7,100	28,000	26,400	61,500
Total, Line item TEC	0	1,342	8,258	28,000	26,400	64,000
Other project costs						
Conceptual design costs	150	0	0	0	0	150
NEPA documentation Costs	5	0	0	0	0	5
Other project related Costs [1]	95	225	100	250	175	845
Total, Other Project Costs	250	225	100	250	175	1,000
Total, Project Cost (TPC)	250	1,567	8,358	28,250	26,575	65,000

7. Related Annual Funding Requirements

(FY 2006 dollars in thousands)

	Current Estimate	Previous Estimate
Annual facility operating costs	$18,000	$18,000
Total related annual funding (operating from FY 2006 through FY 2046)	$18,000	$18,000

[1] Experimental research will begin at the time of beneficial occupancy of the facility. These research costs are not part of the TPC and will be funded by BES.

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.

04-R-313, Molecular Foundry
Lawrence Berkeley National Laboratory, Berkeley, California

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 2004 Budget Request *(Preliminary Estimate)*	3Q2002	1Q2004	2Q2004	2Q2006	$83,700	$85,000

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Project Engineering And Design (PED)			
2002	500	500	38
2003	6,800	6,800	5,972
2004	0	0	1,290
Construction			
2004	35,000	35,000	16,660
2005	32,000	32,000	32,500
2006	9,400	9,400	26,640
2007	0	0	600

3. Project Description, Justification and Scope

The proposed Molecular Foundry at LBNL will be a new structure near the National Center for Electron Microscopy. The project includes an approximately 80,000 gross square foot research building, a separate approximately 5,000 gross square foot utility center, and an initial set of special equipment to support nanoscale scientific research. The research building will be an advanced facility with state-of-the-art clean rooms for the design, modeling, synthesis, processing, fabrication and characterization of novel molecules and nanoscale materials. Space in the new facility will support studies in nanostructures by providing offices and laboratories for materials science, physics, chemistry, biology, and molecular biology. These laboratories, equipped with advanced instrumentation and staffed by full-time, dedicated staff scientists and technicians, will be user facilities, available to scientists from universities, industry, and government laboratories whose research proposals will have been peer reviewed by a Proposal Study Panel. This combination of advanced equipment, collaborative staff, and breadth across disciplines will allow users to explore the frontiers of nanoscience.

The goals and operation of the Molecular Foundry are consistent with DOE guidance and address the research challenges described in the reports *Nanoscale Science, Engineering and Technology Research Directions* and *Complex Systems: Science for the 21st Century.* The Foundry's laboratories will be designed and constructed to facilitate collocation of research activities in a wide variety of fields, as required for progress in this new area of science. The Foundry will support a broad research effort focusing on both "hard" nanomaterials (nanocrystals, tubes, and lithographically patterned structures) and "soft" nanometer-sized materials (polymers, dendrimers, DNA, proteins, and whole cells), as well as design, fabrication, and study of multi-component, complex, functional assemblies of such materials.

By functioning as a "portal" to Lawrence Berkeley National Laboratory's established major user facilities, the Foundry will also leverage existing nanoscience research capabilities at the Advanced Light Source, the National Center for Electron Microscopy, and the National Energy Research Scientific Computing Center. The research program will, as an additional benefit, provide significant educational and training opportunities for students and postdoctoral fellows as the "first true generation" of nanoscientists.

4. Details of Cost Estimate[1]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary Design & Final Design	4,300	N/A
Design Management costs	1,650	N/A
Total, Design Costs	5,950	N/A
Construction Phase		
Building & Improvements to land	43,300	N/A
Special Equipment[2]	15,300	N/A
Inspection, design and project liaison, check out	1,700	
Construction Management & Project Management	2,150	N/A
Total, Construction Costs	62,450	N/A
Contingencies		
Design Phase	1,330	N/A
Construction Phase	13,970	N/A
Total, Contingencies (18.3% of TEC)	15,300	N/A
Total, Line Item Costs (TEC)	83,700	N/A

5. Method of Performance

An Architect - Engineering firm (AE) with appropriate multi-disciplinary design experience will prepare a building program and design criteria with the support of the LBNL Facilities Department. The AE will also prepare Title I and II design and provide technical oversight during Title III construction. A Construction Management (CM) contractor will perform cost, schedule, and constructability reviews during design. Selection of the CM contractor during the design phases will be based on competitive bidding of the Construction General Conditions. The CM contract will have an option for management

[1] This cost estimate is based on conceptual data. The annual escalation rates assumed in the FY 2003 estimate for FY 2002 through FY 2006, are 2.6%, 2.8%, 2.8%, 2.9% and 2.9% respectively.
[2] Initial research equipment including testing and acceptance.

of the construction process. At the completion of design, the CM contractor will bid out the design to subcontractors. The University will have the option to proceed with the CM contractor or bid the project to a separate subcontractor. Construction subcontract(s) will be awarded on a competitive basis using best value source selection criteria that will include price, safety, and other considerations.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Years	FY 2002	FY 2003	FY 2004	Outyears	Total
Facility Cost						
PED	0	38	5,972	1,290	0	7,300
Construction	0	0	0	16,660	59,740	76,400
Total, Line Item TEC	0	38	5,972	17,950	59,740	83,700
Other Project Costs						
Conceptual design cost	290	440	0	0	0	730
NEPA Documentation Costs	0	40	0	0	0	40
Other project-related costs[1]	120	30	0	0	380	530
Total, Other Project Costs	410	510	0	0	380	1,300
Total, Project Costs (TPC)	410	548	5,972	17,950	60,120	85,000

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 (operating from FY 2006 through FY 2046)	$18,000	N/A

[1] Includes preconceptual data and documentation required for CD-1 and for commissioning and startup. Experimental research will begin at the time of beneficial occupancy of the facility. These experimental research costs are not part of the TPC and will be funded by the BES program.

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 12088A Federal Compliance with Pollution Control Standards, the Occupational Safety and Health Act of 1970, the provisions of Executive Order 12196, the Safety and Health provisions for Federal Employees (CFR Title 29, Chapter XVII, Part 1960); 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. The scientific research which will take place in this facility requires a unique research facility and location as described in Section 3.

04-R-314, The Center for Integrated Nanotechnologies (CINT) Facility, Sandia National Laboratories Albuquerque, New Mexico, and Los Alamos National Laboratory Los Alamos, New Mexico

1. Construction Schedule History

	Fiscal Quarter					
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete	Total Estimated Cost ($000)	Total Project Cost ($000)
FY 2004 Budget Request *(Preliminary Estimate)*	3Q 2002	2Q 2004	3Q 2004	3Q 2007	73,800	75,800

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Project Engineering and Design (PED)			
2002	1,000	1,000	167
2003	3,200	3,200	4,033
Construction			
2004	29,850	29,850	20,000
2005	35,300	35,300	31,300
2006	4,450	4,450	18,300

3. Project Descriptions, Justification and Scope

This project provides materials and services required to design and construct the proposed Center for Integrated Nanotechnologies (CINT) Facility. CINT will be a distributed center operated jointly by Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL). CINT will include a Core Facility in Albuquerque, a Gateway to Sandia, and a Gateway to Los Alamos.

The Core Facility will provide approximately 83,000 gross square feet of laboratory and office space, including state-of-the-art clean rooms with an initial set of nanofabrication and characterization equipment.   This facility will also have general purpose chemistry/biology laboratories and electronic and physical measurement laboratories. Lastly, there will be offices and meetings rooms for the Center staff, SNL/LANL collaborators, Center-sponsored post docs, visiting students and faculty, and industry collaborators.

The Gateway to Sandia will focus on specialized microfabrication and nanomaterials capabilities and expertise. This gateway will utilize existing space in SNL's Integrated Materials Research Laboratory and thus will not require any construction funding. The Gateway to Los Alamos will focus on connecting CINT scientists to the extensive biosciences and nanomaterials capabilities at LANL. The facility will provide approximately 31,000 gross square feet of general purpose chemistry/biology laboratories and characterization laboratories outfitted with an initial set of scientific equipment, as well as office and interaction space.

The primary objective of CINT is to develop the scientific principles that govern the performance and integration of nanoscale materials, thereby building the foundations for future nanotechnologies. The distinguishing characteristic of the Center is its 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. The initial technical focus of CINT will be on the four thrusts that derive from expertise at SNL and LANL: nanophotonics and nanoelectronics; complex functional nanomaterials; nanomechanics; and nanoscale bio-micro interfaces.

No existing facilities at SNL or LANL satisfy the needs and objectives of CINT. The Compound Semiconductor Laboratory (CSRL) and the Microelectronic Development Laboratory (MDL) at SNL have some of the needed capabilities, but they are highly subscribed and not available for exploratory work by students and visitors and do not meet the open environment requirement for NSRCs. Likewise, the Materials Science Laboratory at LANL has some of the needed capabilities but it too is highly subscribed with programmatic deliverables and activities.

4. Details of Cost Estimate [1]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs	2,640	N/A
Design Management Costs	540	N/A
Project Management Costs	400	N/A
Total, Design Costs	3,580	N/A
Construction Phase		
Buildings	35,990	N/A
Special Equipment[2]	15,760	N/A
Standard Equipment	1,540	N/A
Inspection, Design and Project Liaison, Testing, Checkout and Acceptance	2,900	N/A
Construction and Project Management	1,030	N/A
Total, Construction Costs	57,220	N/A
Contingencies		
Design Phase	620	N/A
Construction Phase	12,380	N/A
Total, Contingencies (17.6% of TEC)	13,000	N/A
Total, Line Item Costs (TEC)	73,800	N/A

[1] 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. Escalation rates are taken from the DOE construction project and operating expense escalation rate assumptions (as of January 27, 2002).

[2] Initial research equipment including testing and acceptance.

5. Method of Performance

Contracted Architect-Engineering (AE) support was used for development of the design concept and associated narrative and supporting material for the Conceptual Design Report. Design Criteria and other documents required during the conceptual phase for the Core Facility will be prepared by SNL personnel with external support as needed.

Performance specifications will be prepared by LANL staff with contracted support for the Gateway to Los Alamos Facility. A design-build contract will be awarded to a construction contractor selected using a competitive best value process. The process will consider the bidders' qualifications, experience, and the quoted price.

SNL and LANL personnel will provide project management, design management, and project controls support.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Years	FY 2002	FY 2003	FY 2004	Outyears	Total
Project Cost						
Facility Cost						
Design	0	167	4,033	0	0	4,200
Construction	0	0	0	20,000	49,600	69,600
Total, Line item TEC	0	167	4,033	20,000	49,600	73,800
Other Project Costs						
Conceptual design cost	330	0	0	0	0	330
Other project-related costs [1]	45	425	0	150	1,050	1,670
Total, Other Project Costs	375	425	0	150	1,050	2,000
Total, Project Costs (TPC)	375	592	4,033	20,150	50,650	75,800

[1] Includes tasks such as NEPA documentation, Safety documentation, ES&H Monitoring, Operations and Maintenance Support, Readiness Assessment, and Pre-operational Start-up. Experimental research will begin at the time of beneficial occupancy of the facilities. These research costs are not part of the TPC and will be funded by the BES program.

7. Related Annual Funding Requirements [1]

	(FY 2006 dollars in thousands)	
	Current Estimate	Previous Estimate
Annual facility operating costs	340	N/A
Annual facility maintenance/repair costs	400	N/A
Programmatic operating expenses directly related to the facility	16,920	N/A
Utility costs	840	N/A
Total related annual funding (operating from FY 2006 through FY 2046)	18,500	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 12088A Federal Compliance with Pollution Control Standards, the Occupational Safety and Health Act of 1970, the provisions of Executive Order 12196, the Safety and Health provisions for Federal Employees (CFR Title 29, Chapter XVII, Part 1960); 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. The scientific research which will take place in this facility requires a unique research facility and location as described in Section 3.

[1] These costs are preliminary and based on the conceptual design.

Advanced Scientific Computing Research

Program Mission

In the past two decades leadership in scientific computation has become a cornerstone of the Department's strategy to ensure the security of the nation and succeed in its science, energy, environmental quality, and national security missions. This scientific leadership is critical to the economic health of the nation. The mission of the Advanced Scientific Computing Research (ASCR) program is to underpin DOE's world leadership in scientific computation by supporting research in applied mathematics, computer science and high-performance networks and providing the high-performance computational and networking resources that are required for world leadership in science.

Overview:

Computational modeling and simulation are among the most significant developments in the practice of scientific inquiry in the 20th Century. Scientific computing is particularly important for the solution of research problems that are insoluble by traditional theoretical and experimental approaches, hazardous to study in the laboratory, or time-consuming or expensive to solve by traditional means. All of the research programs in the U.S. Department of Energy's Office of Science—in Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, and High Energy and Nuclear Physics—have identified major scientific challenges that can only be addressed through advances in scientific computing.

ASCR research underpins the efforts of the other programs in the Office of Science. The applied mathematics research activity produces the fundamental mathematical methods to model complex physical and biological systems. The computer science research efforts enable scientists to efficiently perform scientific computations on the highest performance computers available and to store, manage, analyze, and visualize the massive amounts of data that result. The networking research activity provides the techniques to link the data producers, e.g., supercomputers and large experimental facilities with scientists who need access to the data.

ASCR's other principal responsibility is to provide the high-performance computational and networking resources that are required for world leadership in science. Recent dramatic advances in scientific computation by researchers and computer companies underscore the importance of strengthening our position in computational sciences in strategic areas. In March 2002, Japan's NEC Earth Simulator became operational. With a peak speed of 40 teraflops and a demonstrated sustained capability of over 25 teraflops, it is faster by approximately a factor of 50 than the most advanced supercomputer for civilian science in the United States. The potential long-term implications of the Earth Simulator on DOE's computational sciences capability was the principal message of the report on this subject delivered to the Director of the Office of Science by the Advanced Scientific Computing Advisory Committee. To strengthen the program's position in this area, the ASCR program is proposing a new effort in Next Generation Computer Architecture (NGA) to identify and address major bottlenecks in the performance of existing and planned DOE science applications.

The ASCR program supports the Office of Science Strategic Plan's goal of providing extraordinary tools for extraordinary science as well as building the foundation for the research in support of the other goals of the strategic plan. The research programs of ASCR have played a critical role in the evolution of high performance computing and networks. The ASCR program actively contributes to the goals of the *Five Year Strategic Plan* of the Interagency Working Group on Information Technology R&D. In particular, ASCR plays a key role in Large Scale Networking and High End Computing and Computation.

The ASCR program is also responsible for the Laboratory Technology Research subprogram, whose mission is to foster and support high-risk research in the natural sciences and engineering in partnership with the private sector leading to innovative applications relevant to the Nation's energy sector.

The quality of the research supported by the ASCR program is continuously evaluated through the use of merit-based peer review, scientific advisory committees, and interagency coordinating bodies.

How We Work:

The ASCR program uses a variety of mechanisms for conducting, coordinating, and funding research in applied mathematics, network and computer sciences, and in advanced computing software tools. The program is responsible for planning and prioritizing all aspects of supported research, conducting ongoing assessments to ensure a comprehensive and balanced portfolio, regularly seeking advice from stakeholders, supporting core university and national laboratory programs, and maintaining a strong infrastructure to support research in applied mathematics, network and computer science, and advanced computing software tools.

Advisory and Consultative Activities:

The ***Advanced Scientific Computing Advisory Committee (ASCAC),*** established on August 12, 1999, provides valuable, independent advice to the Department of Energy on a variety of complex scientific and technical issues related to the ASCR program. The ASCAC 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. ASCAC's recommendations include advice on long-range plans, priorities, and strategies to address more effectively the scientific aspects of advanced scientific computing including the relationship of advanced scientific computing to other scientific disciplines, and maintaining appropriate balance among elements of the program. This advisory committee plays a key role in assessing the scientific and programmatic merit of presently funded activities and in evaluating plans for the future. The Committee formally reports to the Director, Office of Science and includes representatives from universities, national laboratories, and industries who are involved in advanced computing research. Particular attention is paid to obtaining a diverse membership with a balance among scientific disciplines, institutions, and geographic regions. ASCAC operates in accordance with the Federal Advisory Committee Act (FACA, Public Law 92-463; 92nd Congress, H.R. 4383; October 6, 1972) and all applicable FACA Amendments, Federal Regulations and Executive Orders.

The activities funded by the ASCR program 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 evolved through an interagency coordination process that began under the 1991 High Performance Computing Act as the High Performance Computing, Communications, and Information Technology (HPCCIT) Committee. The Federal IT R&D agencies have established a 10-year record of highly successful collaborative accomplishments in multiagency projects and in partnerships with industry and academic researchers. The multiagency approach leverages the expertise and perspectives of scientists and technology users from many agencies who are working on a broad range of IT research questions across the spectrum of human uses of information technology. DOE has been an active participant in these coordination groups and committees since their inception and the ASCR program will continue to coordinate its activities through these mechanisms including an active role in implementing the federal IT R&D FY 2002-2006 Strategic Plan under the auspices of the National Science and Technology Council and the President's Science Advisor.

ASCR is a participant in the Interagency Committee for Extramural Mathematics Programs (ICEMAP), a coordinating committee with representatives from federal agencies that manage programs in mathematical research, including the National Science Foundation, DOE (through ASCR), the National Aeronautics and Space Administration, the National Institute for Standards and Technology, the Air Force Office of Scientific Research, the Army Research Office, and the Office of Naval Research. Meetings are held to coordinate activities across mathematical research programs, ensuring that the federal agencies coordinate their investments in basic mathematical research. The ASCR program regards ICEMAP as an important component in their efforts to maintain coordination with other federal agencies.

Facility Operations Reviews:

The ASCR program has undertaken a series of operations reviews of the National Energy Research Scientific Computing center (NERSC), the Energy Sciences Network (ESnet), and the Advanced Computing Research Testbeds (ACRTs).

NERSC, operated by the Lawrence Berkeley National Laboratory, annually serves about 2,400 scientists throughout the United States. These researchers work at DOE laboratories, universities, industrial laboratories and other Federal agencies. Allocations of computer time and archival storage at NERSC are awarded to research groups based on a review of submitted proposals. As proposals are submitted, they are subjected to peer review to evaluate the quality of science, the relevance of the proposed research to Office of Science goals and objectives and the readiness of the proposed application to fully utilize the computing resources being requested.

The ESnet, managed and operated by the Lawrence Berkeley National Laboratory, is a high-speed network serving thousands of Department of Energy scientists and collaborators worldwide. A pioneer in providing high-bandwidth, reliable connections, ESnet enables researchers at national laboratories, universities and other institutions to communicate with each other using the collaborative capabilities needed to address some of the world's most important scientific challenges. The ESnet Steering Committee (ESSC) was established in 1985 to ensure that ESnet meets the needs of the Office of Science programs. All program offices in the Office of Science appoint members, who represent their scientific communities, to serve on the ESSC. The ESSC is responsible for reviewing and prioritizing network requirements, for establishing performance objectives, and for proposing innovative techniques for enhancing ESnet capabilities. In addition to the ongoing oversight from the ESSC, ASCR conducts external peer reviews of ESnet performance on a three year interval. The last such review was chaired by a member of ASCAC and took place in September 2001.

Advanced Computing Research Testbeds (ACRTs) play a critical role in testing and evaluating new computing hardware and software. Current testbeds are located at Oak Ridge National Laboratory (IBM Power-4 Technology and CRAY X1 technology). In FY 2002, ASCAC conducted a review of the NERSC and ACRTs. The charge to ASCAC, posed the following questions:

- What is the overall quality of these activities relative to the best-in-class in the U.S. and internationally?
- How do these activities relate and contribute to Departmental mission needs?
- How might the roles of these activities evolve to serve the missions of the Office of Science over the next three to five years?

The essential finding of the Subcommittee is that NERSC and the ACRTs are among the best worldwide in their respective categories. It is the opinion of the Subcommittee that these ASCR activities and the related spin-off research efforts contribute signigicantly to the mission needs of the DOE, and profoundly and positively impact high performance computing activities worldwide. The complete report is available on the web at: http://www.sc.doe.gov/ascr/ASCAC-sub.doc

In FY 2001, ASCR conducted a peer review of the Center for Computational Sciences (CCS) at the Oak Ridge National Laboratory. The findings from this review validated the contributions that the CCS made to the Advanced Computing Research Testbed activity within the ASCR program.

Program Reviews:

The ASCR program conducts frequent and comprehensive evaluations of every component of the program. Results of these evaluations are used to modify program management as appropriate. In FY 2002, ASCAC conducted a review of NERSC and the ACRTs.

In FY 2003, ASCR conducted a peer review of the Numerical Linear Algebra, Optimization, and Predictability Analysis areas within the Applied Mathematics activity. These areas represent 33 percent of this activity. In FY 2004, ASCR will conduct a peer review of the Differential Equations and Advanced Numerical Methods for High Performance Computing areas within the Applied Mathematics activity, representing an additional 33 percent of this activity. In FY 2005, ASCR will conduct a peer review of the remaining 34 percent of the Applied Mathematics activity, which consists of Computational Fluid Dynamics and Meshing Techniques. In FY 2004, ASCR will initiate a comprehensive review of the Computer Science research activity.

In FY 2002, following a comprehensive peer review, the ASCR program approved a proposal from the Lawrence Berkeley National Laboratory (LBNL) to manage and operate the National Energy Research Scientific Computing Center for FY 2002 – FY 2006.

Planning and Priority Setting:

The ASCR program must coordinate and prioritize a large number of goals from agency and interagency strategic plans. One of the most important activities of ASCAC is the development of a framework for the coordinated advance and application of network and computer science and applied mathematics. This framework must be sufficiently flexible to rapidly respond to developments in a fast paced area of research. The key planning elements for this program are:

- The Department and Office of Science Strategic Plan, as updated through program collaborations and joint advisory committee meetings. http://www.science.doe.gov/production/bes/strat_pln.htm
- Scientific Discovery through Advanced Computing (SciDAC) plan delivered to Congress in March 2000. http://www.science.doe.gov/scidac/
- The Interagency Working group for Information Technology Five Year Plan – FY 2002-FY 2006 (with key appendixes)
- ASCAC report on the Japanese Earth Simulator. http://www.sc.doe.gov/ascr/ascac.reports.htm

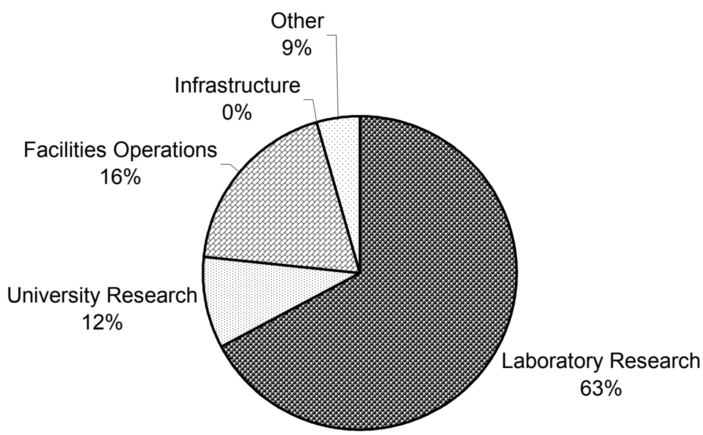
How We Spend Our Budget:

The ASCR program budget has two major components: research and facility testbed and network operations. The FY 2004 budget request continues the core and SciDAC research efforts and strengthens the research partnerships with other SC offices. The testbed and network operations expenditures account for 37 percent of the National Lab Research, or 24 percent of the total ASCR budget.

Research:

Over 76 percent of the program's FY 2004 funding will be provided to scientists at universities and laboratories to conceive and carry out the research or to fund advanced computing testbeds and network operations. National laboratory research scientists work together with the other programs of the Office of Science to develop the tools and techniques that allow those programs to take advantage of terascale computing for scientific research. The laboratories provide state-of-the-art resources for testbeds and novel applications. The division of support between national laboratories and universities is adjusted to maximize scientific productivity.

ADVANCED SCIENTIFIC COMPUTING RESEARCH
FY 2004



- ***University Research***: University researchers play a critical role in the nation's research effort and in the training of graduate students. During FY 2002, the ASCR program supported over 150 grants to the nation's university researchers and graduate students engaged in civilian applied mathematics, large-scale network and computer science research. These grants included support for graduate students. In addition, ASCR supports a Computational Science Graduate Fellowship and an Early Career Principal Investigator Program in Applied Mathematics, Computer Science and High-Performance Networks. In FY 2002, ASCR selected 24 new graduate fellows representing 17 universities and 13 states and expects to make up to forty awards to early career principal investigators. ASCR also provides support to other Office of Science research programs. Approximately one-half of those who received Ph.D.'s in the Computational Sciences Graduate Fellowship program between 1991 and 2001 are pursuing careers outside universities or national labs.

  The university grants program is proposal driven, similar to the computer science and applied mathematics programs at NSF. However, ASCR grant solicitation notices are focused on topics that have been identified as important for DOE missions. ASCR funds the best among the ideas submitted in response to grant solicitation notices (see: www.er.doe.gov/production/grants/grants.html). Proposals are reviewed by external scientific peers and competitively awarded according to the guidelines published in 10 CFR 605 (www.science.doe.gov/production/grants/605index.html).

- *National Laboratory Research*: ASCR supports national laboratory-based research groups at Ames, Argonne, Brookhaven, Los Alamos, Lawrence Berkeley, Lawrence Livermore, Oak Ridge, Pacific Northwest, and Sandia National Laboratories. The directions of laboratory research programs are driven by the needs of the Department and the unique capabilities of the laboratories to support large scale, multidisciplinary, collaborative research activities. In addition, laboratory-based research groups are highly tailored to the major scientific programs at the individual laboratories and the computational research needs of the Office of Science. Laboratory researchers collaborate with laboratory and academic researchers, and are important for developing and maintaining testbeds and novel applications of high performance computing and networking in Office of Science research. At Los Alamos, Livermore and Sandia, ASCR funding plays an important role in supporting basic research that can improve the applied programs, such as the Accelerated Strategic Computing Initiative (ASCI) and the Science Stockpile Stewardship program.

ASCR funds field work proposals from the national laboratories. Proposals are reviewed by external scientific peers and awarded using procedures that are equivalent to the 10 CFR 605 guidelines used for the grants program. Performance of the laboratory groups is reviewed by ASCR staff annually to examine the quality of their research and identify needed changes, corrective actions or redirection of effort. Individual laboratory groups have special capabilities or access to laboratory resources that can be profitably utilized in the development of the research program.

Program Strategic Performance Goals

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

Eighty percent of all new research projects will be peer reviewed and deemed excellent and relevant, and annually 30 percent of all ongoing projects will be subject to peer review with merit evaluation; all research areas and facilities will be periodically reviewed by subcommittees of the Advanced Scientific Computing Advisory Committee and determined to be world class.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Completed 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) [Met Goal]	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)	Define, based on the analysis completed in FY 2003, a research strategy that will deliver by 2007 effective operating systems for high performance scientific computers with 20,000 or more processors. (SC5-1)
		Complete, by the end of FY 2004, a roadmap that defines the critical, applied mathematics research issues which must be addressed to enable the development of mathematical algorithms that can operate efficiently on computers with thousands of

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
		processors and address the needs of DOE mission applications. This roadmap will be completed through a series of workshops sponsored by ASCR and ASCAC.
Appointed 25 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) [Exceeded Goal]		
		Respond to recommendations of Advanced Scientific Computing Advisory Committee sub panel on computational biology.

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 (trillions of operations per second) 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

Validation of results by merit review with external peer evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Achieved 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) [Met Goal] Migrated the users with the largest allocations to the IBM-SP from the previous generation Cray T3E. (SC5-2) [Met Goal]	Begin installation of next generation NERSC computer, NERSC-4, that will at least double the capability available in FY 2002 to solve leading edge scientific problems. (SC5-2)	Complete installation of next generation NERSC computer, NERSC-3e, that will at least double the capability available to solve leading edge scientific problems. The number of Massively Parallel Processor Hours (MPP Hours) available will increase from 53 million in FY 2003 to 110 million in FY 2004.
	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	Deliver enhanced versions of software from Integrated Software Infrastructure Centers established in FY 2001 to scientific application research teams. This software will increase the average efficiency of those applications by 50% (from the current 10% average baseline efficiency of peak processor power to 15%). This improvement in efficiency

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
	Biological and Environmental Research and Basic Energy Sciences programs, respectively, of submitted proposals. (SC5-2)	will enable a 30% increase in the amount of science research/analysis that can be accomplished at the existing high performance computing facilities.
	Evaluate effectiveness of a new software tool-(GRID middleware) as a tool to enable SC user communities in High Energy Physics and Global Climate to effectively access very large data resources over the Internet.	Plan upgrade of ESnet that will satisfy transatlantic data requirements of Large Hadron Collider (LHC) experiment at CERN outside of Geneva, Switzerland.

SC7-5: Provide advanced scientific user facilities where scientific excellence is validated by external review; average operational downtime does not exceed 10 percent of schedule; construction and upgrades are within 10 percent 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.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 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)
Deliver preliminary report of ASCAC review of ASCR high performance computing facilities. (SC7-5) [Met Goal]	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)	Complete the review of ASCR high performance network facilities by the Advanced Scientific Computing Advisory Committee (ASCAC) and implement action plans to respond to recommendations.

Program Assessment Rating Tool (PART) Assessment

The Office of Management and Budget has provided the ASCR program with input using their Program Assessment Rating Tool (PART). The OMB states that ASCR's program has a fairly well defined mission and merit-based reviews for awarding contracts and grants, leading to high scores for both purpose and management practices. Despite the problems inherent in predicting and then measuring scientific progress, the OMB has acknowledged that ASCR has made significant strides in developing long-term and annual performance measures. The OMB also stated that in the past several years, ASCR has recast its focus between several large initiatives since 2000. The OMB suggested that this situation reflected a lack of long-term vision for the program, and recommended that ASCR develop a long-term strategic plan. The OMB also noted that the ASCR program does not yet have regular reviews of its research portfolio and processes by a Committee of Visitors (COV). Both suggestions have been adopted by ASCR as action items to be completed by the end of FY 2003.

Significant Program Shifts

The ASCR program advances mathematics and computer science, and develops the specialized algorithms, the scientific software tools, and the software libraries needed by DOE researchers to effectively use high-performance computing and networking hardware for scientific discovery. The ASCR program has been a leader in the computational sciences for several decades and has been acknowledged for pioneering accomplishments.

High-performance computing and networking resources will be provided to meet the needs of the base research programs throughout the Office of Science. Research efforts initiated in FY 2001 in Scientific Discovery through Advanced Computing (SciDAC) will be continued, as planned. The FY 2004 budget includes $13,968,000 to launch a research investment in Next Generation Computer Architecture for science. The NGA will increase the delivered computing capability available to address the Office of Science mission through optimization of computer architectures to meet the special requirements of scientific problems. This investment positions the nation to realize extraordinary scientific opportunities in computing for science and enable new classes of scientific problems to be addressed. The NGA effort complements SciDAC and integrates advanced computer architecture researchers and engineers, application scientists, computer scientists, and applied mathematicians.

The computational needs of the SciDAC research program will be addressed by investments focused on providing high-performance computing pilot capability for Topical Applications. The FY 2004 budget request includes $7,867,000 for continued support of the Genomes to Life research program, in partnership with the Biological and Environmental Research program; and $3,072,000 for the Nanoscale Science, Engineering and Technology initiative led by the Basic Energy Sciences program. ASCR's contributions to these partnerships will consist of advancing the mathematics and developing new mathematical algorithms to simulate biological systems and physical systems at the nanoscale.

In FY 2004, the Mathematical, Information and Computational Sciences subprogram will continue to support core research activities at current levels.

The Laboratory Technology Research subprogram will be brought to a successful conclusion in FY 2004.

Interagency Environment

The activities funded 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 evolved through 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 an active participant in these coordination groups and committees since their inception. The MICS subprogram will continue to coordinate its activities through these mechanisms and will lead the development of new coordinating mechanisms as needs arise. The DOE program solves mission critical problems in scientific computing. In addition, results from the DOE program benefit the Nation's Information Technology Basic Research effort. The FY 2004 program positions DOE to make additional contributions to this effort. In the area of high performance computing and computation, ASCR has extensive partnerships with other Federal agencies and the NNSA. Examples include: acting as a technical agent for one of the DARPA High Productivity Computing Systems contracts; serving on the planning group for the Congressionally mandated DOD plan for high performance computing to serve the national security mission; and extensive collaboration with NNSA-Advanced Simulation Computing.

Scientific Discovery through Advanced Computing

The SciDAC activity is a set of coordinated investments across all Office of Science mission areas with the goal to achieve breakthrough scientific advances through computer simulation that were impossible using theoretical or laboratory studies alone. By exploiting advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model for multi-discipline collaboration among the scientific disciplines, computer scientists and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can fully exploit terascale computing and networking resources. The program will bring simulation to a parity level with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate prediction, plasma physics, particle physics, astrophysics and computational chemistry.

Next Generation Computer Architecture

The goal of the Next Generation Computer Architecture (NGA) research activity is to identify and address major architectural bottlenecks, such as internal data movement in very large systems, in the performance of existing and planned DOE science applications. Emphasis will be placed on understanding the impact of alternative computer architectures on application performance with particular attention paid to data movement from memory to processor and between processors in highly parallel systems. Software research will be initiated to improve application performance and system reliability through innovative approaches to next generation operating systems. Emphasis will also be placed on hardware evaluation testbeds of sufficient size to understand key issues impacting application performance scalability and portability. The NGA activity will be coordinated with other Federal agencies to gain additional insight into research directions, optimize the utilization of resources, and establish the framework for a national effort.

Scientific Facilities Utilization

The ASCR program request includes support to the National Energy Research Scientific Computing (NERSC) Center, a component of the Office of Science-wide Scientific Facilities Initiative. This investment will provide computer resources for about 2,400 scientists in universities, DOE laboratories, federal agencies, and U.S. companies. The proposed funding will enable NERSC to maintain its role as one of the Nation's premier unclassified computing centers, a critical element for success of many Office of Science research programs.

(hours)	FY 2000	FY 2001	FY 2002	FY 2003 Est.	FY 2004 Est.
Maximum Hours – NERSC	8,760	8,760	8,760	8,760	8,760
Scheduled Hours – NERSC	8,497	8,585	8,585	8,585	8,585
Unscheduled Downtime – NERSC	1%	1%	1%	–	–

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 2004, 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.

	FY 2000	FY 2001	FY 2002	FY 2003 est.	FY 2004 est.
# University Grants	128	170	163	144	140
Size, Duration	$95,000/yr-3 yrs	$157,000/yr-3yrs	$157,000/yr-3yrs	$197,000/yr-3yrs	$197,000/yr-3yrs
# Lab Groups	148	226	209	165	165
# Grad Students	290	370	354	354	354
# PhD's Awarded	550	660	604	675	675

Funding Profile

	(dollars in thousands)				
	FY 2002 Comparable Appropriation	FY 2003 Request	FY 2004 Request	$ Change	% Change
Advanced Scientific Computing Research					
Mathematical, Information, and Computational Sciences	147,159	163,557	170,490	+6,933	+4.2%
Laboratory Technology Research	3,046	3,000	3,000	0	--
Total, Advanced Scientific Computing Research	150,205[abc]	166,557[c]	173,490	+6,933	+4.2%

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 $3,731,000 which was transferred to the SBIR program and $224,000 which was transferred to the STTR program.
[b] Excludes $88,000 for the FY 20023 rescission contained in section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to Terrorist attacks on the United States.
[c] Excludes $3,068,000 in FY 2002, FY 2003 and FY 2004 for Homeland Security activities that are funded in a separate Department of Homeland Security budget.

Funding by Site[a]

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	3,709	5,020	3,570	-1,450	-28.9%
Sandia National Laboratories	5,783	3,889	6,047	+2,158	+55.5%
Total, Albuquerque Operations Office	9,492	8,909	9,617	+708	+7.9%
Chicago Operations Office					
Ames Laboratory	2,183	1,625	1,578	-47	-2.9%
Argonne National Laboratory	13,503	8,573	11,646	+3,073	+35.8%
Brookhaven National Laboratory	1,359	542	960	+418	+77.1%
Fermi National Accelerator Laboratory	326	60	226	+166	+276.7%
Princeton Plasma Physics Laboratory	400	0	420	+420	+100.0%
Chicago Operations Office	17,147	7,240	24,556	+17,316	+239.2%
Total, Chicago Operations Office	34,918	18,040	39,386	+21,346	+118.3%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	65,872	53,223	57,686	+4,463	+8.4%
Lawrence Livermore National Laboratory	4,119	0	3,068	+3,068	+100.0%
Stanford Linear Accelerator Center	702	234	613	+379	+162.0%
Oakland Operations Office	2,122	960	3,115	+2,155	+224.5%
Total, Oakland Operations Office	72,815	54,417	64,482	+10,065	+18.5%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science and Education	306	99	200	+101	+102.0%
Oak Ridge National Laboratory	26,629	10,496	9,819	-677	-6.4%
Thomas Jefferson National Accelerator Facility	100	0	0	0	--
Total, Oak Ridge Operations Office	27,035	10,595	10,019	-576	-5.4%
Richland Operations Office					
Pacific Northwest National Laboratory	4,097	1,003	3,601	+2,598	+259.0%
Washington Headquarters	1,848	73,593	46,385	-27,208	-37.0%
Total, Advanced Scientific Computing Research	150,205	166,557	173,490	+6,933	+4.2%

[a] On December 20, 2002, the National Nuclear Security Administration (NNSA) disestablished the Albuquerque, Oakland, and Nevada Operations Offices, renamed existing area offices as site offices, established a new Nevada Site Office, and established a single NNSA Service Center to be located in Albuquerque. Other aspects of the NNSA organizational changes will be phased in and consolidation of the Service Center in Albuquerque will be completed by September 30, 2004. For budget display purposes, DOE is displaying non-NNSA budgets by site in the traditional pre-NNSA organizational format.

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 ANL also focuses on testing and evaluating leading edge research computers. 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. BNL has a computing capability for Quantum Chromodynamics (QCD) simulations. 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 participation in base research and SciDAC efforts.

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. 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 126 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 Measures

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.

The computing and the networking required to meet Office of Science needs exceed the state-of-the-art by a wide margin. Furthermore, the algorithms, software tools, the software libraries and the software environments needed to accelerate scientific discovery through modeling and simulation are beyond the realm of commercial interest. To establish and maintain DOE's modeling and simulation leadership in scientific areas that are important to its mission, the MICS subprogram employs a broad, but integrated research strategy. The MICS subprogram's basic research portfolio in applied mathematics and computer science provides the foundation for enabling research activities, which includes efforts to advance networking, to develop software tools, software libraries and software environments. Results from enabling research supported by the MICS subprogram are used by computational scientists supported by other Office of Science and other DOE programs. This link to other DOE programs provides a tangible assessment of the value of the MICS subprogram for advancing scientific discovery and technology development through simulations.

In addition to its research activities, the MICS subprogram plans, develops, and operates 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.

The Early Career Principal Investigator (ECPI) activity was initiated in FY 2002 for scientists and engineers in tenure track positions at U.S. universities. Seventeen (17) awards were made. The goal of the ECPI activity is to support Office of Science mission related research in applied mathematics, computer science and high-performance networks performed by exceptionally talented university investigators, who are at an early stage in their professional careers.

ACCOMPLISHMENTS

- **ParamBench demonstrates the significant impact of concurrent memory accesses -** Computer scientists at the Lawrence Livermore National Laboratory, in collaboration with researchers at the University of Utah and North Carolina State University have implemented ParamBench, low-level benchmarks of memory performance in symmetric multiprocessors (SMPs). These benchmarks measure the raw memory performance of SMPs, including the effect of multiple processors accessing the memory system concurrently. Results with this benchmark suite demonstrate that standard latency-hiding techniques, such as hardware prefetching, are less effective in SMPs, even with a crossbar-based memory interconnection.
- **New Analysis Tools for Innovative Materials -** Mathematicians at the Oak Ridge National Laboratory have extended the class of materials science problems that can be solved by a powerful technique known as the "Boundary Element Method." This numerical method significantly

reduces the number of operations that are needed to solve materials science problems, but has traditionally been applicable only to homogeneous materials. The researchers derived the fundamental solution to a set of integral equations for "Functionally Graded Materials," an important class of materials that are not homogeneous, but whose properties vary smoothly. These materials already play an important role in many applications, including coatings for protecting turbine blades, special optical materials, and dental implants and other bio-materials.

- **Scientific Data Objects: A Common Language for Exchanging Parallel Data** - Arrays, or matrices, are one of the basic data structures of scientific computing. In large-scale simulations, arrays are often so large that they must be distributed across many processors. In order for different software modules to work together on a distributed array, a method must exist to precisely describe the distribution of the data. As part of the SciDAC Center for Component Technology for Simulation Software, researchers at the Oak Ridge National Laboratory developed such a description, thus greatly simplifying the development of components that need to exchange distributed array data objects with other components. The new interface specification is capable of describing the layouts used by a wide range of distributed array tools, including CUMULVS (ORNL), Global Arrays (PNNL), High Performance Fortran, A++/P++ (LLNL), and others.
- **New Scientific Data Index Performs 100 Times Faster Than Commercial Database Systems -** Terascale computing and large scientific experiments produce enormous quantities of data that require effective and efficient management. The task of managing scientific data is overwhelming. Researchers at the Lawrence Berkeley National Laboratory have developed a specialized index for accessing very large datasets that contain a large number of attributes that may be queried. This new index performs 12 times faster than the previous best-known method, and 100 times faster than conventional indexing methods in commercial database systems. The prototype index is being used by researchers in high energy physics and combustion modeling.
- **Faster Reconstruction Methods are Making Waves -** Mathematicians at the Lawrence Berkeley National Laboratory have developed efficient and fast techniques for solving the problem of multiple arrivals; that is, detecting and separating the arrival of waves that have taken differing paths through a medium. Example applications include geophysical analysis, which is important for oil exploration, and antenna design. The methods are fast enough that they can be embedded inside "inverse solvers," computer codes that use information about the arriving waves to deduce the characteristics of an unknown body between the source and detector. This will result in new computational tools to examine hidden objects, accurately reconstruct inaccessible regions, and rapidly test proposed models.
- **Increasing Scientific Productivity through Automated Optimization** - Many complex problems in science, engineering and business require the solution of optimization problems, but the conventional approach to solving such problems can be extremely time-consuming and difficult to apply. Researches at Argonne National Laboratory have developed the Network-Enabled Optimization System (NEOS) that allows users to solve optimization problems over the Internet with state-of-the-art software and without tedious downloading and linking of specialized optimization code. Because of its ease of use, the NEOS server has gained widespread popularity with more than 5,000 job requests each month from users around the world. Recent NEOS applications include circuit simulation, protein folding, circuit design, brain modeling, airport crew scheduling, and modeling of electricity markets.

- **OSCAR Cluster Software Distribution A Big "Hit" Worldwide -** The Open Source Cluster Application Resources package, OSCAR, is a collection of software tools for managing Linux-based computer clusters developed by a consortium of academic, research, and industry members led by scientists at the Oak Ridge National Laboratory. According to the Top 500 Clusters web site, OSCAR has become the most used cluster computing distribution available today. OSCAR is also used as the core cluster base package in the MacNeil Schwindler (MSC) Linux commercial cluster distribution as well as the NCSA "in-a-box" series of cluster computing solutions. OSCAR has a "market share" of over 30% according to the poll – more than twice its nearest competitor. OSCAR has been downloaded over 53,000 times and has received over 140,000 web page hits during the past year.
- **Tiled Displays: Automatic Calibration of Scalable Display Systems -** Today's scientific simulations and rich multimedia collaborative environments can easily produce many millions to tens of millions of pixels for display. Tiled display systems built by combining the images from arrays of projectors can provide massive numbers of pixel elements to visually represent large amounts of information. Multiprojector tiled arrays can be a cost-effective way to create these displays, and they may be the only practical way to create large information dense displays. But, it is difficult to create the illusion of a unified seamless display for a variety of reasons, including projector-to-projector color and luminosity differences, variation of luminosity across the image from a single projector, and optical distortion of the individual projector images caused by imperfections in the lenses and misalignment of projectors. Researchers at Argonne National Laboratory have developed methods to attack these fundamental issues which provide an efficient and optimized measurement process using inexpensive components that is tolerant of a wide range of imperfections in components and measurement setup such as lighting conditions and camera optics.
- **NERSC Improves Supercomputer Performance.** The Department of Energy's National Energy Research Scientific Computing (NERSC) Center at the Lawrence Berkeley National Laboratory has improved the utilization of its 5 Tflops supercomputer, NERSC-3. After only six months of operation, NERSC-3 began to deliver 90-95% of its cycles to users, on a routine basis.
- **ESnet deploys next general protocol** – ESnet has deployed Internet Protocol Version 6 (IPv6) on its production network. Enabling IPv6 on the network brings a new level of security (e.g. packet encryption and source authentication) and supports real-time traffic, such as video conferencing. IPv6 is expected to become the protocol of choice throughout the Internet.

AWARDS

Top Young Innovator Award – A computer scientist at Argonne National Laboratory has been named one of the world's top 100 young innovators by Technology Review, MIT's Magazine of Innovation. The list recognizes 100 individuals under the age of 35 whose innovative work in business and technology is having a profound influence on today's world. This scientist's work centers on development of Grid technologies for connecting geographically dispersed resources. He also leads standardization efforts of the Globus Project™.

Scientific Computing Research Investments

High-performance computing hardware is important for meeting DOE's modeling and simulation needs. However, computer hardware can only enable scientific advances when the appropriate algorithms, scientific software tools, libraries, software environments, and the networking infrastructure are easy to use and are readily available to the users. The MICS subprogram differs from high performance computing efforts in other Federal agencies because of its management focus to integrate research investments to enable new science. Desktop systems realize advances in computing power primarily through increases in the processor's clock speed. High performance computers employ a different strategy for achieving performance, complicating the architecture and placing stringent requirements on software. The MICS subprogram supports software research over a broad range, but that research is tailored to DOE's science needs. Research is underway to improve the performance of simulations on high-end computers, to remove constraints on the human-computer interface and to discover the specialized information management and analysis techniques that scientists need to manage, analyze and visualize extremely large data files.

Technology trends and business forces in the U.S. computer system industry over the past decade caused most domestic vendors to curtail or abandon the development of high-end systems designed to meet the most demanding requirements of scientific research. Instead, large numbers of smaller commercial systems were combined and integrated into terascale computers to achieve the peak performance levels required for agency missions in computational science. The hardware is complicated, unwieldy and not balanced for scientific applications. Enabling software has been developed for scientists to take advantage of these new computers. However, this software is extraordinarily complex. Consequently, the DOE, primarily through the MICS subprogram, and other Federal agencies whose missions depend on high-performance computing, must make basic research investments to adapt high-performance computing and networking hardware into tools for scientific discovery.

To make progress in the future, our current strategy needs to be adjusted. Continued emphasis on developing software-based solutions to enable scientific simulations on large clusters of computers designed for mid-range applications is no longer the basis for a sustainable strategy for many high-end applications. Rather, our emphasis needs to broaden to include computer hardware technology, architecture, and design trends motivated from a scientific user perspective. This can be accomplished by making research investments that couple computational scientists and computer scientists with U.S. computer vendors to orient future computer architectures towards the need of science. Additional research investments would be made to ensure that the software takes full advantage of the computer architecture. The status of the technology, the conditions of the current business market for computing, and the success of the Earth Simulator supercomputer in Japan are strong indicators that this strategy will provide tangible near-term results for scientific simulation. This revised strategy is the tenet for the NGA effort. While NGA will be instrumental in removing architectural bottlenecks to performance on actual scientific simulations, others will remain and possibly become persistent obstacles in the future.

To illustrate the complexities involved, think of a high-performance computer as a large number of conference rooms distributed around a region. Each conference room is connected through the region's transportation and communications infrastructure. Now, the task of a successful scientific application is analogous to getting everyone in the region to a pre-assigned conference room on time. Instructions are given to each participant (systems software). Results from each conference (calculations) will be documented (stored in memory) for distribution. New conferences are convened, new instructions are given and new decisions are made. Now repeat this process trillions of times, as occurs in a scientific simulation! As one can appreciate, this process can only work if the region's infrastructure is properly configured and operating efficiently. That is, the buses, subways, taxicabs, roads, elevators and telephones can efficiently handle the demand. Most of the systems available from computer vendors are analogous to small regions, a limited number of conference rooms and an inefficient infrastructure. Computers for scientific simulation on the other hand, must be analogous to large cities, large numbers of conference rooms, and an efficient infrastructure, with alternative modes of transportation and communication.

Advances in *computer science* research can enable scientists to overcome these remaining barriers. For example,

- 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; and
- provide computational scientists with tools, options, and strategies to obtain the maximum scientific benefit from their computations.

Research advances in computer science do not provide the full range of capabilities that computational scientists need, especially for the complex problems faced by the Office of Science. Significant efforts in the applied mathematical research activity will be required for the Department to satisfy its mission requirements for computational science. Historically, improvements in mathematical algorithms have yielded at least as much increase in performance as have improvements in hardware. A large proportion of these advances resulted from the MICS subprogram applied mathematics research activity. 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 scientists. In this area of research, the MICS applied mathematics activity is the core of the nationwide effort.

The MICS subprogram research activities that respond to these challenges are described below in the Detailed Program Justification section of the MICS subprogram budget under the headings:

- Applied Mathematics
- Computer Science
- 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 solutions to complex problems. It is now becoming possible to harness and integrate the collective capabilities of large geographically distributed data archives, research teams, and computational resources. This collective 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. To successfully realize the potential of this collective research capability, additional research is needed to bring network, data, and computational resources to the members of a distributed team in a manner that is easy to use and guarantees end-to-end performance. For example:

- Significant research is needed to augment the capability of the Internet to support distributed high-end data-intensive applications and to secure large-scale scientific collaborations. 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.
- 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. This high-performance middleware provides the scalable software components needed to integrate data, visualization, computation and high-speed networks into a scalable and secure scientific collaborative environment.

The MICS subprogram will address these challenges through fundamental research in networking; software tools that integrate networking and computer science to enable scientific collaboration (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
- 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, massive data resources and other leading-edge instruments and facilities.
- **Advanced Computing Research Testbeds.** The Advanced Computing Research Testbeds (ACRTs) consist of high performance, advanced architecture computing platforms for testing and evaluation to ascertain the prospects for meeting future general, or specialized, computational science needs of the Office of Science. In FY 2004, the ACRTs will provide hardware resources for the NGA activity. Two types of computing platforms will be evaluated - early systems from vendors, and experimental systems. Based on an analysis of vendor offerings and a peer review of the potential that such offerings can meet Office of Science computational needs, hardware will be acquired at sufficient scale to address key performance and software scaling issues. The evaluation process will include computer science studies and tests of leading-edge Office of Science computational science applications, such as those being developed under SciDAC. In addition, the ACRTs will provide computing resources to SciDAC teams.
- **Trends for Future Supercomputing and Networking Resources.** The need for high performance computational resources will increase in future years as applications transition from the software development and testing phase to using the software to generate new science. As the peak performance of the computers increase, the amount of data produced in a simulation increases as well. 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 and by large-scale science experiments.

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
- Energy Sciences Network (ESnet)

Subprogram Goals

The MICS subprogram goals are identical to the ASCR program goals, and the performance indicators and targets for ASCR apply directly to the activities of the MICS subprogram. Therefore, no subprogram goals are included in the MICS section of the ASCR budget.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Mathematical, Computational, and Computer Sciences Research	52,877	75,633	83,300	+7,667	+10.1%
Advanced Computation, Communications Research and Associated Activities	94,282	83,782	82,591	-1,191	-1.4%
SBIR/STTR	0	4,142	4,599	+457	+11.0%
Total, Mathematical, Information, and Computational Sciences	147,159	163,557	170,490	+6,933	+4.2%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Mathematical, Computational, and Computer Sciences Research	**52,877**	**75,633**	**83,300**
■ **Applied Mathematics**	**22,655**	**23,141**	**22,634**

This activity supports research on the underlying mathematical understanding of physical, chemical and biological systems, and on advanced numerical algorithms that enable effective description and prediction of such systems on terascale computing systems. Research in Applied Mathematics supported by MICS underpins computational science throughout DOE. Historically, the numerical algorithms developed under this activity have produced more scientific advances through simulation than improvements in computer hardware. This activity supports research at DOE laboratories, universities, and private companies. Many of the projects supported by this activity involve research partnerships between DOE's national laboratories and universities. The activity supports research in a wide variety of areas of mathematics, including: ordinary and partial differential equations and solutions methods, including techniques to convert equations into discrete elements and boundary integral methods, advanced treatment of interfaces and boundaries, (fast marching and level set methods, and front tracking); numerical linear algebra (advanced iterative methods, general and problem-specific preconditioners, sparse solvers, and dense solvers); fluid dynamics (compressible, incompressible and reacting flows, turbulence modeling, and multiphase flows); optimization (linear and nonlinear programming, interior-point methods, and discrete and integer programming); mathematical physics; control theory (differential-algebraic systems, order reduction, and queuing theory); accurate treatment of shock waves; "fast" methods (fast multipole and fast wavelet transforms); mixed elliptic-hyperbolic systems; dynamical systems (chaos theory, optimal control theory, and bifurcation theory); and automated reasoning systems.

The FY 2004 budget continues the Computational Sciences Graduate Fellowship program at the current level of $3,500,000.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

The decrease in funding for this activity between FY 2003 and FY 2004 includes the transfer of Genomes to Life activities to Scientific Application Partnerships to better reflect the character of the research. In FY 2003, $1,491,000 was transferred to the Department of Homeland Security for evaluation of applied mathematical sciences activities at the Lawrence Livermore National Laboratory to determine which are most suitable for transfer to the Department of Homeland Security.

■ **Computer Science**	**19,517**	**17,506**	**23,680**

This activity supports research in computer science to enable researchers to effectively utilize high-performance computers to advance science in areas important to the DOE mission. DOE has unique requirements for high performance computing that significantly exceed the capability of software products from computer vendors. This activity supports computer science 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, propose and conduct this research.

In FY 2003, $1,491,000 was transferred to the Department of Homeland Security for evaluation of computer science activities at the Lawrence Livermore National Laboratory to determine which are most suitable for transfer to the Department of Homeland Security. *In addition, the FY 2004 budget includes $4,659,000 for an academic and domestic computer vendor research effort on future generation operating systems and runtime environments. Critical goals for this NGA effort will be to enable future operating systems runtime environments to deliver maximum performance to scientific applications. Projects will be competitively selected.*

■ **Advanced Computing Software Tools**.................................	**5,543**	**20,256**	**20,256**

This activity supports research that builds on the results from research in applied mathematics and computer science to develop integrated software tools that computational scientists can use to develop high performance applications (such as characterizing and predicting phase changes in materials). These tools, which enable 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 2004, this activity will continue to support the Integrated Software Infrastructure Centers (ISICs), a SciDAC activity, competitively selected in FY 2001. 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

	FY 2002	FY 2003	FY 2004

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 SciDAC strategy. The ISICs are responsible for the entire lifecycle of the software that they develop. These software tools must be reliable, understandable and well documented. Also, the scientific user community to be maintained, bug-free and upgraded, as necessary. Software for tools high performance scientific simulations have no commercial market. The Integrated Software Infrastructure Centers initiated in FY 2001 provide the only means for developing and deploying these tools to the scientific community.

	FY 2002	FY 2003	FY 2004
■ **Scientific Applications Partnerships**	**5,162**	**14,730**	**16,730**

This activity, formerly titled Scientific Application Pilot Projects, supports collaborative research with disciplinary computational scientists to apply the computational techniques and tools developed by other MICS activities to address problems relevant to the mission of SC. This effort tests the usefulness of advances in computing research, transfers the results of this research to the scientific disciplines, and helps define opportunities for future research. The FY 2004 funding for this activity will allow the continuation of the partnerships that were competitively selected in FY 2001. These projects are part of the SciDAC activity and are coupled to the Integrated Software Infrastructure Centers. Areas under investigation include design of particle accelerators with the High Energy Physics (HEP) and Nuclear Physics (NP) programs; 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 FY 2004 request includes funds to continue the partnership with the Biological and Environmental Research program Genomes to Life and the partnership with the Basic Energy Sciences program in nanoscale science. *The FY 2004 in request also includes $2,000,000 to support research under the NGA to understand the relationship among programming models, architecture features and application performance. Projects will be selected through a peer reviewed, open competition.*

	FY 2002	FY 2003	FY 2004
Advanced Computation, Communications Research, and Associated Activities	**94,282**	**83,782**	**82,591**
■ **Networking**	**7,329**	**7,066**	**7,066**

This activity supports research and development in high-performance networks needed to develop and deploy advanced networking capabilities to address challenging issues such as ultra-high-speed data transfers, remote visualization, real-time remote instrumentation, and large-scale scientific collaboration. Networking research is carried out at national laboratories and universities and consists of two major elements:

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

Network R&D – to address the fundamental issues of high-performance networks to support access to the next generation of scientific facilities, terascale computing resources and distributed petabyte-scale data archives. Network R&D focuses on leading-edge networking technologies such as ultra optical transport protocols and services for ultra high-speed data transfers; techniques and tools for ultra high-speed network measurement and analysis; advanced network tools and services to enable network-aware, high-end scientific applications; and scalable cyber-security technologies for open science environment.

Advanced experimental networking – to accelerate the adoption of emerging networking technologies and to transfer networking R&D results into production networks that support science applications. It includes activities such as experimental networking testbeds, advanced deployment and evaluation of new networking technologies, and exploration of advanced networking concepts. A rapid adoption of emerging network capabilities into production networks will enable scientists pushing the limits of today's networks capabilities to use networking technologies to conduct far-reaching experiments.

	FY 2002	FY 2003	FY 2004
■ **Collaboratory Tools**	**7,000**	**5,527**	**5,527**

This activity supports research that builds on 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 throughout 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 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.

	FY 2002	FY 2003	FY 2004
■ **National Collaboratory Pilot Projects**................................	**9,384**	**10,857**	**10,857**

This activity supports research that tests, validates, and applies 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

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

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 (HEP) and Nuclear Physics (NP) 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 is 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 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 distributed computation.

	FY 2002	FY 2003	FY 2004
■ **National Energy Research Scientific Computing Center (NERSC)**	**31,244**	**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; 35 percent of users are university based, 61 percent are in National Laboratories, 3 percent are in industry, and 1 percent in other government laboratories. The major computational resource at NERSC is an IBM SP computer. The initial installation of hardware, which was completed in FY 2001 following a fully competitive process, provided a peak performance of 5 trillion floating point operations per second (teraflops) to its users. The capability of this system was increased to 10 teraflops following the acquisition of additional computer hardware in FY 2003. The FY 2004 funding will support the continued operation of the IBM SP computer at 10 teraflops peak performance. These computational resources are 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 2004 capital equipment requirements remain at the same level as in FY 2003.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
■ **Advanced Computing Research Testbeds (ACRTs)**............	**20,295**	**15,300**	**12,609**

This activity supports the acquisition, the testing and the evaluation of advanced computer hardware testbeds to assess the prospects for meeting future computational needs of the Office of Science, such as SciDAC and special purpose applications. The ACRT activity will provide two types of computer testbeds for evaluation - early systems and experimental systems. Each testbed will involve significant research and architecture design activities. *The FY 2004 request includes $7,309,000 to complete the evaluation of Cray X1 hardware that was initiated in FY 2002. The reduction in this activity will allow the program to focus on a single new evaluation under the NGA and provide critical resources to SciDAC teams.*

■ **Energy Sciences Network (ESnet)**..	**19,030**	**16,788**	**18,288**

ESnet is a high-performance network infrastructure that supplies the DOE science community with capabilities not available through commercial networks or the commercial Internet. ESnet provides national and international high-speed access to DOE and Office of Science researchers and research facilities, including: light sources; neutron sources; particle accelerators; fusion reactors; spectrometers; supercomputers; and other high impact scientific instruments. ESnet provides the communications fabric that interconnects geographically distributed research facilities and large-scale scientific collaborations. ESnet 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. ESnet provides network services through contracts with commercial vendors for advanced communications services including Asynchronous Transfer Mode (ATM), Synchronous Optical Networks (SONET) and Dense Wave Division Multiplexing (DWDM). ESnet provides 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. In FY 2004, funds will be used to operate ESnet and to continue support for upgrading the capability of the ESnet backbone to 10,000 million bits per sec (Mbps) from its current capability of 155 Mbps. Remaining funds will be used to upgrade networking hardware and services at high priority ESnet sites to exploit the enhanced performance capabilities of the backbone.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
SBIR/STTR	**0**	**4,142**	**4,599**

In FY 2002, $3,656,000 and $220,000 were transferred to the SBIR and STTR programs, respectively. The FY 2003 and FY 2004 amounts are the estimated requirement for the continuation of the SBIR and STTR program.

Total, Mathematical, Information, and Computational Sciences	**147,159**	**163,557**	**170,490**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Mathematical, Computational, and Computer Sciences Research	
■ **Applied Mathematics.** The decrease results from the transfer of Genomes to Life activities to Scientific Application Partnerships to better reflect the character of the research, partially offset by increases to core Applied Mathematics research. Funding for Homeland Security in FY 2003 is budgeted by the Department of Homeland Security in FY 2004.	-507
■ **Computer Science.** Provides an increase under the NGA for an academic and domestic computer vendor research effort. Includes an increase to provide core research infrastructure for NGA. Funding provided for Homeland Security in FY 2003 is budgeted by the Department of Homeland Security in FY 2004.	+6,174
■ **Scientific Application Partnerships.** Provides an increase to support research under the NGA to understand the relationship among programming models, architecture features and application performance.	+2,000
Total Mathematical, Computational, and Computer Sciences Research	+7,667
Advanced Computation, Communications Research, and Associated Activities	
■ **Advanced Computing Research Testbed.** Reduction in this program to focus on single new evaluation under the NGA and providing critical resources to SciDAC teams.	-2,691
■ **ESnet.** Provides an increase in this program element for upgrades to the ESnet infrastructure for an architecture tailored to a class of applications within the SciDAC research portfolio to produce new science	+1,500
Total Advanced Computation, Communications Research, and Associated Activities	-1,191

	FY 2004 vs. FY 2003 ($000)
SBIR/STTR	
■ Increase in SBIR/STTR due to increase in operating expenses.	+457
Total Funding Change, Mathematical, Information, and Computational Sciences	+6,933

Laboratory Technology Research

Mission Supporting Goals and Objectives

The Laboratory Technology Research (LTR) subprogram is being brought to a successful conclusion in FY 2004. The mission of the Laboratory Technology Research 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.

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 2002	FY 2003	FY 2004	$ Change	% Change
Laboratory Technology Research	3,046	2,921	2,916	-5	-0.2%
SBIR/STTR	0	79	84	+5	+6.3%
Total, Laboratory Technology Research	3,046	3,000	3,000	0	--

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Laboratory Technology Research	**3,046**	**2,921**	**2,916**

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.

	FY 2002	FY 2003	FY 2004
SBIR/STTR	**0**	**79**	**84**

In FY 2002, $75,000 and $4,000 were transferred to the SBIR and STTR programs, respectively. The FY 2003 and FY 2004 amounts are the estimated requirement for the continuation of the SBIR and STTR program.

	FY 2002	FY 2003	FY 2004
Total, Laboratory Technology Research	**3,046**	**3,000**	**3,000**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
There are no significant funding changes.	

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
General Plant Projects..........................	0	1,000	0	-1,000	-100.0%
Capital Equipment (total)	3,777	6,250	6,250	0	--
Total, Capital Operating Expenses	3,777	7,250	6,250	-1,000	-13.8%

Science Laboratories Infrastructure

Program Mission

The mission of the Science Laboratories Infrastructure (SLI) program is to enable the conduct of Departmental research missions at the ten Office of Science (SC) laboratories and the Oak Ridge Institute for Science and Education (ORISE) by funding line item construction to maintain the general purpose infrastructure (GPI) and the clean-up and removal of excess facilities. The program 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.

Significant Program Shifts

- The program was broadened in FY 2003 to include all SC program dedicated laboratories and ORISE along with the multiprogram laboratories. These program dedicated laboratories include Ames Laboratory, Fermi National Accelerator Laboratory, Princeton Plasma Physics Laboratory, Thomas Jefferson National Accelerator Facility, and Stanford Linear Accelerator Center.

- In FY 2003 an Excess Facilities Disposition subprogram was presented in the Science Laboratories Infrastructure program to address the disposition of excess facilities resulting in economies and efficiencies in laboratory operations. This subprogram continues the Facilities and Infrastructure (F&I) program initiated in FY 2002.

- Progress in Line Item Projects – Three projects were completed in FY 2002: the LBNL Building 77 Rehabilitation of Structures and Systems, Phase I; ORNL Roofing Improvements; 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. Five projects are scheduled for completion in FY 2004: BNL Ground and Surface Water Protection Upgrades; BNL Electrical Systems Modifications, Phase II; LBNL Site-wide Water Distribution System Upgrades; ORNL Laboratory Facilities HVAC Upgrade; and the ORNL Fire Protection System Upgrades. In FY 2004, one new project, SLAC Safety and Operational Reliability Improvements, is proposed.

Funding Profile

(dollars in thousands)

	FY 2002 Comparable Appropriation	FY 2003 Request	FY 2004 Request	$ Change	% Change
Science Laboratories Infrastructure (SLI)					
Laboratories Facilities Support	22,691	32,601	33,456	+855	+2.6%
Excess Facilities Disposition	9,960	5,055	5,055	0	--
Oak Ridge Landlord	4,474	5,079	5,079	0	--
External Regulation	0	0	0	0	0
Total, Science Laboratories Infrastructure	37,125[ab]	42,735	43,590	+855	+2.0%

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 included in the Science Laboratories Infrastructure program (Excess Facilities Disposition) in FY 2003 and FY 2004.

[b] Excludes $5,000 for the FY 2002 rescission contained in section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to terrorist attacks on the United States.

Funding by Site[a]

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Chicago Operations Office					
Argonne National Laboratory	3,643	4,205	6,002	+1,797	+42.7%
Brookhaven National Laboratory	7,413	8,513	5,917	-2,596	-30.5%
Fermi National Accelerator Laboratory	53	0	233	+233	+100.0%
Princeton Plasma Physics Laboratory	875	545	980	+435	+79.8%
Chicago Operations Office	894	1,020	1,520	+500	+49.0%
Total, Chicago Operations Office	12,878	14,283	14,652	+369	+2.6%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	6,900	5,607	2,975	-2,632	-46.9%
Lawrence Livermore National Laboratory	350	250	250	0	--
Stanford Linear Accelerator Center	400	0	2,000	+2,000	+100.0%
Total, Oakland Operations Office	7,650	5,857	5,225	-632	-10.8%
Oak Ridge Operations Office					
Thomas Jefferson National Accelerator Facility	0	1,500	3,914	+2,414	+160.9%
Oak Ridge National Laboratory	10,745	12,016	10,600	-1,416	-11.8%
Oak Ridge Institute for Science and Education	0	0	0	0	--
Oak Ridge Operations Office	4,474	5,079	5,079	0	--
Total, Oak Ridge Operations Office	15,219	18,595	19,593	+998	+5.4%
Richland Operations Office					
Pacific Northwest National Laboratory	1,377	4,000	4,120	+120	+3.0%
Washington Headquarters	1	0	0	0	--
Total, Science Laboratories Infrastructure	37,125[b]	42,735	43,590	+855	+2.0%

[a] On December 20, 2002, the National Nuclear Security Administration (NNSA) disestablished the Albuquerque, Oakland, and Nevada Operations Offices, renamed existing area offices as site offices, established a new Nevada Site Office, and established a single NNSA Service Center to be located in Albuquerque. Other aspects of the NNSA organizational changes will be phased in and consolidation of the Service Center in Albuquerque will be completed by September 30, 2004. For budget display purposes, DOE is displaying non-NNSA budgets by site in the traditional pre-NNSA organizational format.

[b] FY 2002 Appropriation provided $10,000,000 in a new program added by Congress titled "Facilities and Infrastructure." Funding for this activity is included in the Science Laboratories Infrastructure program (Excess Facilities Disposition) in FY 2003 and FY 2004.

Site Description

Ames Laboratory

Ames Laboratory (Ames) 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 is located on the campus of the University of Iowa, in Ames, Iowa, and consists of 10 buildings (320,000 gross square feet of space) with the average age of the buildings being 37 years. DOE does not own the land.

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 106 buildings (4.6 million gross square feet of space) with the average age of the buildings being 32 years. The line item construction backlog identified in the laboratory's Strategic Facilities Plan is $190,000,000. The SLI program will continue to fund the following project in FY 2004:

- MEL-001-017 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).

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 371 buildings (4.1 million gross square feet of space) with the average age of the buildings being 41 years. The line item construction backlog identified in the laboratory's Strategic Facilities Plan is $376,000,000. The SLI program will continue to fund the following project in FY 2004:

- MEL-001-027 Research Support Building, Phase I (TEC $18,200,000) This 55,000 sq. ft. facility 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, 23,000 sq. ft. of World War II era structures will be torn down. Based on total life-cycle costs, productivity gains, avoided energy and maintenance costs, the Research Support Building, Phase I will provide a return on investment of 14.4% and a simple payback of 9 years.

Fermi National Accelerator Laboratory

Fermi National Accelerator Laboratory is the center for research in high-energy and particle physics and constructs and runs large particle accelerators. The laboratory is located in Batavia, Illinois, and consists of 337 buildings (2.2 million gross square feet of space) with the average age of the buildings being 37 years. The line item construction backlog identified in the laboratory's Strategic Facilities Plan is $7,000,000.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located on a 200 acre site owned by the University of California that is adjacent to the Berkeley campus of the University of California in Berkeley, California. The laboratory consists of 107 buildings (1.68 million gross square feet of space) with the average age of the buildings being 37 years. The line item construction backlog identified in the laboratory's Strategic Facilities Plan is $148,000,000. The SLI program will continue to fund the following project in FY 2004:

- MEL-001-028 Building 77 Rehabilitation of Structures and Systems, Phase II (TEC $13,360,000) This project will provide for the rehabilitation to correct mechanical, electrical, and architectural deficiencies in Buildings 77 (a 39 year old, 68,000 sq. ft. high-bay industrial facility) and 77A (a 14 year old, 10,000 sq. ft. industrial facility). Both buildings house machine shop and assembly operations in which production of highly sophisticated research components for a variety of DOE research projects is performed. 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 completed in FY 2002, corrected 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 in Oak Ridge, Tennessee. The laboratory's 1,100 acre main site on Bethel Valley Road contains 335 buildings (3 million gross square feet of space) with the average age of the buildings being 32 years. The line item construction backlog identified in the laboratory's Strategic Facilities Plan is $209,000,000. The SLI program will continue to fund the following project in FY 2004:

- MEL-001-025 - 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 support staff. 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. 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 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 laboratory 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 40 government owned buildings (900,000 gross square feet of space) with the average age of the buildings being 31 years. PNNL also has 451,000 square feet of space in Battelle owned buildings on Battelle owned land. The line item construction backlog identified in the laboratory's Strategic Facilities Plan is $19,000,000. The SLI program will continue to fund the following project in FY 2004:

- MEL-001-018 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, replacing them with more efficient and 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; and installation of computerized, remote, digital controls on various systems to improve operations.

Princeton Plasma Physics Laboratory

Princeton Plasma Physics Laboratory (PPPL) is a 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 on Princeton University land, and consists of 35 buildings (700,000 gross square feet of space) with the average age of the buildings being 23 years. The line item construction backlog identified in the laboratory's Strategic Facilities Plan is $13,000,000.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center (SLAC) is a laboratory dedicated to the design, construction and operation of state-of-the-art electron accelerators and related experimental facilities for use in high-energy physics and synchrotron radiation research. SLAC operates the 2 mile long Stanford Linear Accelerator which began operating in 1966. SLAC is located on 426 acres of Stanford University land in Menlo Park, California, and is also the home of the Stanford Synchrotron Radiation Laboratory

(SSRL). The SSRL was built in 1974 to utilize the intense x-ray beams from the Stanford Positron Electron Accelerating Ring (SPEAR) that was built for particle physics by the SLAC laboratory. SLAC (including SSRL) consists of 166 buildings (1.8 million gross square feet of space) with the average age of 23 years. The line item construction backlog identified in SLAC's (including SSRL) Strategic Facilities Plan is $15,000,000. The SLI program will initiate the following project in FY 2004:

- MEL-001-036 - Safety and Operational Reliability Improvements (TEC $15,600,000) – This project has two components:

    - Underground Utility Upgrades - this component will replace deteriorated sections of cooling water, low conductivity water, drainage, natural gas, compressed air and fire protection which are critical to the operation of the linear accelerator and the B Factory rings which produce the essential collisions needed for the Charge-Parity Violation studies (one of the pillars of the current U.S. High Energy Physics program also carried out competitively at KEK in Japan). There have been five pipe failures over the last two years and the failure rate is expected to increase in these 35 year-old systems as they continue to age. When the pipes fail, research is slowed or halted until repairs are completed.

    - Seismic Upgrades – this component will install seismic upgrades necessary to bring various building structures into compliance with the seismic standards of the Uniform Building Code. The seismic hazard in the Bay Area is high. Nineteen "essential" facilities, i.e., those that will minimize the time required for the Laboratory to recover from an earthquake, will be retrofitted for a total of 229,000 sq. ft. Payback is nine years.

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 65 buildings (500,000 gross sq. ft. of space) with the average age of the buildings being 12 years. The line item construction backlog identified in the lab's Strategic Facilities Plan is $24,000,000. The SLI program will continue to fund the following project in FY 2004:

- MEL-001-033 Continuous Electron Beam Accelerator Facility (CEBAF) Center Addition, Phase I (TEC $10,500,000) - This project is Phase I of three phases to provide for additions to the CEBAF Center office building. The purpose of the three phases is to provide additional critical computer center space and to eliminate off-site leases and existing trailers to collocate staff for enhanced productivity. This first addition will add 59,000 sq. ft. of computer center (7,600 sq. ft) and office space and eliminate 22,000 sq. ft. of aging trailers with a 7.4-year simple payback and a 10% rate of return. Phase I will provide additional space for 182 users and 50 staff personnel.

Chicago Operations Office

The Chicago Operations Office processes the Payments in Lieu of Taxes (PILT) made to the local taxing authorities at Brookhaven National Laboratory and Argonne National Laboratory-East. 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.

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 (ORR) outside plant fences and activities to maintain a viable operations office, including maintenance of roads and grounds and other infrastructure, PILT, and other needs related to landlord activities.

Laboratories Facilities Support

Mission Supporting Goals and Measures

The Laboratories Facilities Support (LFS) subprogram improves the mission readiness of Office of Science (SC) laboratories by funding line item construction projects to refurbish or replace general purpose facilities and the site-wide infrastructure. General purpose and site-wide infrastructure includes administrative, research laboratory, user support and testing space as well as cafeterias, power plants, fire stations, electrical, gas and other utility distribution systems, sanitary sewers, roads, and other associated structures. The 10 SC laboratories have over 2,400 buildings (including 787 trailers and 150 excess buildings) with a total square footage of over 21,000,000 square feet.

Capital investment requirements for SC laboratories are identified in laboratory Strategic Facilities Plans. These plans assume the full modernization/revitalization of the infrastructure of the laboratories will be completed over a ten-year period and include priority lists of proposed facilities and infrastructure needs. The backlog of line item construction modernization needs as summarized in SC's "*Infrastructure Frontier: A Quick Look Survey of the Office of Science Laboratory Infrastructure*," April 2001, is on the order of $1 billion. Nearly 85% of this total is to rehabilitate or replace buildings.

The large backlog of line item construction needs 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);
- the use of wood and other non-permanent building materials in the original construction of the laboratories in the 40's and 50's;
- changing research needs that require:
  - different kinds of space (e.g., nuclear facilities including hot cells are in less demand while facilities that foster interaction and team-based research are in high demand) and;
  - higher quality of space (e.g., reduced vibration sensitivity and temperature variability, and increased air quality and power demand for computers and other electronic equipment, etc.)
- obsolescence of existing building systems and components and changing technology (e.g., digital controls for heating and ventilation systems, fire alarms, security, etc.);
- increased requirements for continuity of utility operations to support large user population at SC user research facilities;
- increased energy costs;
- changing environmental, safety and health regulations and security needs; and
- inadequate capital investment in the past.

For each budget, all candidate construction projects for funding by the LFS subprogram are scored 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 scores, the LFS subprogram prioritizes the projects. The prioritized list is further evaluated for SC science program mission impact by an integrated infrastructure management team composed of the LFS subprogram and SC research program offices. Projects are then proposed from this list consistent with budget availability.

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). Three projects scheduled for completion in FY 2002 were completed within the approved baselines for cost, scope, and schedule. The LFS subprogram also provides Payments in Lieu of Taxes (PILT) assistance for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory-East.

Subprogram Goals

Reduce the Recapitalization Period (RP) of the general purpose infrastructure (GPI) from 146 years in FY 2002 to 112 years in FY 2004. The RP is defined as the number of years it takes to replace/rehabilitate the GPI at a specified capital investment level. The period is computed by dividing the replacement plant value of GPI ($5,975,000,000 in FY 2002) by the annual capital investment funding level for GPI. The annual capital investment funding level for GPI is composed of general purpose line item funding and one half the general plant projects (GPP) funding (i.e., GPP is small construction up to $5,000,000). One-half of the GPP is used because, on average, one half funds GPI related small construction and the other half funds programmatic small construction needs. Note: Because SC research programs fund GPP - e.g., Basic Energy Sciences funds GPP at Argonne National Laboratory, Oak Ridge National Laboratory, and Ames Laboratory, this measure reflects SC's corporate efforts for capital investment in the GPI. (Laboratories Facilities Support subprogram)

Performance Indicator

The reduction in the RP from year to year

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Based on capital investment funding level of $40,840,000 for FY 2002, the RP will be 146 years.	Based on proposed capital investment funding level of $54,299,000 for FY 2003, the RP will decline to 112 years.	Based on proposed capital investment funding level of $54,428,000 for FY 2004, the RP will be 112 years.

Funding Schedule

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
General Purpose Facilities	5,380	19,107	24,784	+5,677	+29.7%
Environment, Safety and Health	16,416	12,474	7,152	-5,322	-42.7%
Payment in Lieu of Taxes (PILT)	895	1,020	1,520	+500	+49.0%
Total, Laboratories Facilities Support	22,691	32,601	33,456	+855	+2.6%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
General Purpose Facilities	**5,380**	**19,107**	**24,784**

Provides funding to support continuation of two FY 2002 subprojects and three FY 2003 subprojects under the Science Laboratories Infrastructure (MEL-001) Project Engineering and Design (PED) and construction project data sheets. These are summarized below. More details are provided in the data sheets presented later.

Ongoing projects:

- LBNL Building 77 Rehabilitation of Structures and Systems, Phase II ($2,000,000)
- BNL Research Support Building, Phase I ($5,150,000)
- TJNAF CEBAF Center Addition, Phase I ($3,914,000)
- PNNL Laboratory Systems Upgrade ($4,120,000)
- ORNL Research Support Center ($9,600,000).

Environment, Safety and Health	**16,416**	**12,474**	**7,152**

Provides funding to support the initiation of one new subproject in FY 2004 as well as the continuation of one FY 2002 subproject under the Science Laboratories Infrastructure (MEL-001) PED and construction project data sheets. These are summarized below. More details are provided in the data sheets presented later.

Ongoing:

- ANL-E Mechanical and Control Systems Upgrades, Phase I ($5,152,000)

New Start:

- SLAC Safety and Operational Reliability Improvements ($2,000,000)

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
PILT	**895**	**1,020**	**1,520**

Increase Payments in Lieu of Taxes (PILT) to support the negotiated increase in the per acre land value used to calculate the PILT payment. PILT assistance requirements for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory-East are negotiated between the Department and local governments based on land values and tax rates.

Total, Laboratories Facilities Support	**22,691**	**32,601**	**33,456**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Laboratories Facilities Support	
■ Increase in the General Purpose Facilities (GPF) area reflects the completion of several ES&H projects resulting from significant past ES&H investment and shifting program priorities to GPF needs.	+5,677
■ Reduction in the Environment, Safety and Health (ES&H) area reflects the completion of several ES&H projects resulting from significant past ES&H investment and shifting of program priorities to GPF needs. Funding is included for a high priority new ES&H project start at SLAC.	-5,322
■ Increase in PILT funding to meet increased tax rates and assessments	+500
Total Funding Change, Laboratories Facilities Support	+855

Excess Facilities Disposition

Mission Supporting Goals and Measures

The Excess Facilities Disposition (EFD) subprogram removes excess facilities at the SC laboratories to reduce long-term costs and liabilities in support of 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 reuse is economical and can provide needed functionality.

The EFD subprogram evaluates and prioritizes the backlog based on 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). The prioritized list is further evaluated for mission impact by an integrated infrastructure management team composed of the EFD subprogram and SC research program offices. The estimated backlog of non-contaminated or slightly contaminated facilities at the beginning of FY 2004 will be approximately $16,000,000.

The EFD subprogram does not fund projects that replace currently active and occupied buildings (e.g., old, deteriorated and marginally functional ones that are still used but are to be replaced by new modern buildings). Such building replacement projects are funded under the previously described LFS subprogram and would include removal of the old buildings as part of the justification for the project.

Subprogram Goals

Eliminate the current backlog of excess SC facilities by the end of FY 2006. (Excess Facilities Disposition subprogram)

Performance Indicator

Reductions as measured by the number of excess facilities and square footage removed (or made usable).

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
A Congressionally added FY 2002 Facilities and Infrastructure (F&I) Program of $10,000,000 will allow the clean-up of approximately 30 excess facilities with a reduction of approximately 400,000 square feet in FY 2002.	Estimated clean-up of 9 facilities with a reduction of approximately 113,000 square feet.	Estimated clean-up of 13 facilities with a reduction of approximately 92,000 square feet. Expect to eliminate current backlog by the end of FY 2006, two years earlier than planned. However, additional needs may be identified.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Excess Facilities Disposition	9,960	5,055	5,055	0	--
Total, Excess Facilities Disposition	9,960	5,055	5,055	0	--

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Excess Facilities Disposition...	**9,960**	**5,055**	**5,055**

FY 2002 Facilities and Infrastructure (F&I) program funding of $9,960,000 allows for the clean-up/removal of approximately 30 excess facilities. In FY 2002, an estimated 400,000 total square feet of space is being removed or cleaned up for reuse in the projects listed below:

- 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.)
- FNAL ($53,000) – Demolition of Neon Compressor Building (approximately 900 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 and shielding block removals (approximately 27,000 sq. ft.)

In FY 2003, funding of $5,055,000 supports the 6 projects listed below and allows for the clean-up/removal of an estimated 113,000 square feet of space:

- 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, 90, 91 and 118 (approximately 32,000 sq. ft.)
- LBNL ($950,000) – Disposal of concrete shield blocks, beamlines, magnets, and activated components (approximately 2,000 sq. ft.)
- LLNL ($250,000) – Demolish Magnetic Fusion Energy bridge and utility lines (approximately 1,000 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) control room and initial subsystem removals (approximately 12,000 sq. ft.)

In FY 2004, funding of $5,055,000 supports 7 projects listed below and allows for the clean-up/removal of an estimated 92,000 square feet of space:

- ANL-E ($850,000) - Building 205 (H-125/H-126 Cell) Decontamination and Decommissioning, and Building 330 (CP-5) Partial Disposal (approximately 35,000 sq. ft.).
- BNL ($767,000) - Demolition of Buildings 208, 324, and 428 (approximately 21,000 sq. ft.)
- FNAL($233,000) –Bubble Chamber Demolition (approximately 3,000 sq. ft.)
- LBNL ($975,000) - Disposal of Pill Box Roof Concrete Blocks from Building 51 (2,000 sq. ft.)
- LLNL ($250,000) - Demolition of Magnetic Fusion Energy Legacy Facilities at Building 445 (approximately 8,000 sq. ft.)
- ORNL ($1,000,000) - Deactivation/Demolition of Building 1506 and Demolition of Freel's Bend and Solway Facilities, (approximately 5,000 sq. ft.)
- PPPL ($980,000) Princeton Beta Experiment Modification (PBX) Princeton Large Torus (PLT) final subsystem removals and cooling tower demolition (approximately 18,200 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.

Total, Excess Facilities Disposition	**9,960**	**5,055**	**5,055**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Excess Facilities Disposition No funding change.	

Oak Ridge Landlord

Mission Supporting Goals and Measures

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).

This subprogram supports landlord responsibilities, including infrastructure for the 24,000 acres of the ORR outside of the Y-12 plant, ORNL, and the East Tennessee Technology Park, plus 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 2002 there were no significant interruptions due to infrastructure failures.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Oak Ridge Landlord	4,474	5,079	5,079	0	--

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
■ **Roads, Grounds and Other Infrastructure and ES&H Support and Improvements**	**2,195**	**2,488**	**2,488**
■ **Payments in Lieu of Taxes (PILT)**	**1,900**	**2,300**	**2,300**

Payments in Lieu of Taxes (PILT) to the City of Oak Ridge, and Anderson and Roane Counties.

	FY 2002	FY 2003	FY 2004
■ **Reservation Technical Support**	**379**	**291**	**291**

Includes recurring activities such as Site Mapping, National Archives Records Administration, and support for legacy legal cases.

	FY 2002	FY 2003	FY 2004
Total, Oak Ridge Landlord	**4,474**	**5,079**	**5,079**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Oak Ridge Landlord	

No funding change.

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ 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 2002	FY 2003	FY 2004	Unapprop. Balance
Project – 02-SC-001 Laboratories Facilities Support Project						
FY 2002 PED Datasheet	N/A	N/A	3,183	0	0	0
Project – 03-SC-001 Laboratories Facilities Support Project						
FY 2003 PED Datasheet	N/A	N/A	0	3,355	0	0
Project – 04-SC-001 Laboratories Facilities Support Project						
FY 2004 PED Datasheet	N/A	N/A	0	0	2,000	0
Project - MEL-001 Laboratories Facilities Support Project						
FY 2004 Construction Datasheet	N/A	N/A	18,613	28,226	29,936	28,489
Total, LFS Construction	N/A	N/A	21,796	31,581	31,936	28,489

04-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
2004	2,000	2,000	1,600
2005	0	0	400

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 updated request provides the status of ongoing PED projects funded in FY 2002 and proposed in FY 2003. This PED data sheet requests design funding for one FY 2004 new start: Stanford Linear Accelerator Center – Safety and Operational Reliability Improvements.

FY 2004 Proposed Design Projects

Environment, Safety, and Health Project:

04 -04: MEL-001-036 – Safety and Operational Reliability Improvements (SLAC)

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 2004	3Q 2004	4Q 2004	N/A	2,000	15,600

Fiscal Year	Appropriations	Obligations	Costs
2004	2,000	2,000	1,600
2005	0	0	400

This project has two components:

- Underground Utility Upgrades - this component will replace deteriorated sections of cooling water, low conductivity water, drainage, natural gas, compressed air and fire protection which are critical to the operation of the linear accelerator and the B Factory rings which produce the essential collisions needed for the Parity Violation studies (one of the pillars of the current US High Energy Physics program also carried out competitively at KEK in Japan). There have been five pipe failures over the last two years and the failure rate is expected to increase in these 35 year-old systems as they continue to age. When the pipes fail, research is slowed or halted until repairs are completed.
- Seismic Upgrades – this component will install seismic upgrades necessary to bring various building structures into compliance with the seismic standards of the Uniform Building Code. The seismic hazard in the Bay Area is high. 19 "essential" facilities, i.e., those that will minimize the time required for the Laboratory to recover from an earthquake, will be retrofitted for a total of 229,000 sq. ft. Payback is 9 years.

FY 2003 Ongoing Design Projects

(dollars in thousands)

(Design Project No. PED-03-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:								
03 -01: MEL-001-028 Building 77 Rehabilitation Of Structures and Systems, Phase II	LBNL	1,100	0	0	0	1Q2003	2Q2004	3Q2004

This project will provide for rehabilitation to correct mechanical, electrical and architectural deficiencies in Buildings 77 (a 39 year old, 68,000 sq. ft. high-bay industrial facility) and 77A (a 14 year old, 10,000 sq. ft. industrial facility). Both buildings house machine shop and assembly operations in which production of highly sophisticated research components for a variety of DOE research projects is performed. 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 completed in FY 2002, corrected structural deficiencies in Bldg. 77.

(dollars in thousands)

(Design Project No. PED-03-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)
03 -02: MEL-001-027 Research Support Building, Phase I	BNL	1,710	0	0	0	1Q2003	2Q2004	3Q2004

This design project will provide design for construction of the Research Support Building, Phase I. This 55,000 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, 23,000 sq. ft. of World War 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.

(dollars in thousands)

(Design Project No. PED-03-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)
03 -03: MEL-001-033 CEBAF Center Addition, Phase I	TJNAF	545	0	0	0	1Q2003	4Q2003	1Q2004

This project is Phase I of three phases to provide for additions to the CEBAF Center office building. The purpose of the three phases is to provide additional critical computer center space and to eliminate off-site leases and existing trailers to collocate staff for enhanced productivity. This first addition will add 59,000 sq. ft. of computer center (7,600 sq. ft) and office space and eliminate 22,000 sq. ft. of aging trailers with a 7.4-year simple payback and a 10% rate of return. Phase I will provide additional space for 182 users and 50 staff personnel.

FY 2003 Total		3,355	0	0	0

FY 2002 Ongoing 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	880	622	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, replacing them 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.

(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)
02-03: MEL-001-025 Research Support Center	ORNL	1,500	1,500	1,500	522	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 offices for support staff. 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. 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, 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 laboratory now undergoing decontamination. The estimated simple payback is seven years.

(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)

Environment, Safety & Health Projects:

02-08: MEL-001-017 Mechanical Control Systems Upgrade, Ph. I	ANL	803	803	803	230	1Q2002	3Q2003	2Q2003

(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)

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	3,183	1,374			

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 2003 Congressional Budget Request are denoted with a vertical line in the left margin.)

1. Construction Schedule History

Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		

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	2,000	2,000	2,080
FY 2005	0	0	500
Construction			
Prior Years	10,879	10,879	2,672
FY 2002	18,613	18,613	12,262
FY 2003	28,226	28,226	27,445
FY 2004	29,936	29,936	31,900
FY 2005	28,489	28,489	29,400
FY 2006	0	0	12,464

[a] Title I and Title II Design funding of $880,000 (Subproject 18); $803,000 (Subproject 17); and $1,500,000 (Subproject 25) provided under 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 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 user 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 15 – Laboratory Facilities HVAC Upgrade (ORNL)

TEC	Prev.	FY 2002	FY 2003	FY 2004	Outyear	Construction Start/ Completion Dates
7,100	500	3,000	3,600	0	0	3Q 2002 – 2Q 2004

This project will provide improvements to aging (average 38 years old) HVAC systems located throughout the 13 buildings which comprise ORNL's central research complex, thereby improving the research environment and reducing operations and maintenance costs. Work will include: 1) installation of a primary/secondary Central Chilled Water Plant pumping system by replacing existing inefficient primary and booster pumps with a variable volume distribution system and 2-way chilled water control valves; 2) installation of a chilled water cross-tie to Buildings 4501/4505 from the underground tie-line between Buildings 4500N and 4509 to address low capacity problems; 3) upgrading of a corroded hot water reheat distribution system which supplies reheat water for zone control of the primary air handlers; 4) upgrade of deteriorated air handlers in selected buildings with new filters, steam and chilled water coils, and controls; 5) installation of new chilled water coils and chilled water supply piping for the east wing of Building 3500 to replace the refrigerant system that has high maintenance requirements; and 6) replacement of control valves in various buildings to improve system efficiency.

b. Subproject 18 – Laboratory Systems Upgrades (PNNL)

TEC	Prev.	FY 2002	FY 2003	FY 2004	Outyear	Construction Start/ Completion Dates
9,000	0	880[a]	4,000	4,120	0	2Q 2003 – 2Q 2005

This project will upgrade or replace 20-50 year old mechanical system components in eight high occupancy facilities, replacing them with more efficient and 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.

[a] Title I and Title II Design funding provided under PED Project No. 02-SC-001.

c. Subproject 25 – Research Support Center (ORNL)

TEC	Prev.	FY 2002	FY 2003	FY 2004	Outyear	Construction Start/ Completion Dates
16,100	0	1,500[a]	5,000	9,600	0	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 support staff. 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. 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, 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 laboratory now undergoing decontamination. The estimated simple payback is seven years.

d. Subproject 27 – Research Support Building, Phase I (BNL)

TEC	Prev.	FY 2002	FY 2003	FY 2004	Outyear	Construction Start/ Completion Dates
18,200	0	0	3,250[b]	5,150	9,800	2Q 2004 – 3Q 2006

This 55,000 sq. ft. facility 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, 23,000 sq. ft. of World War 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.

[a] Title I and Title II Design funding of $1,500,000 provided under PED Project No. 02-SC-001.
[b] Title I and Title II Design funding of $1,710,000 requested under PED Project No. 03-SC-001.

e. Subproject 28 – Building 77 Rehabilitation of Structures and Systems, Phase II (LBNL)

TEC	Prev.	FY 2002	FY 2003	FY 2004	Outyear	Construction Start/ Completion Dates
13,360	0	0	1,757[a]	2,000	9,603	3Q 2004 – 2Q 2006

This project will provide for rehabilitation to correct mechanical, electrical and architectural deficiencies in Buildings 77 (a 39 year old, 68,000 sq. ft. high-bay industrial facility) and 77A (a 14 year old, 10,000 sq. ft. industrial facility). Both buildings house machine shop and assembly operations in which production of highly sophisticated research components for a variety of DOE research projects is performed. 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 completed in FY 2002, corrected structural deficiencies in Bldg. 77.

f. Subproject 33 – Continuous Electron Beam Accelerator Facility (CEBAF) Center Addition, Phase I (TJNAF)

TEC	Prev.	FY 2002	FY 2003	FY 2004	Outyear	Construction Start/ Completion Dates
10,500	0	0	1,500[b]	3,914	5,086	1Q 2004 – 1Q 2006

This project is Phase I of three phases to provide for additions to the CEBAF Center office building. The purpose of the three phases is to provide additional critical computer center space and to eliminate off-site leases and existing trailers to collocate staff for enhanced productivity. This first addition will add 59,000 sq. ft. of computer center (7,600 sq. ft.) and office space and eliminate 22,000 sq. ft. of aging trailers with a 7.4-year simple payback and a 10% rate of return. Phase I will provide additional space for 182 users and 50 staff personnel.

ES&H Projects:

a. Subproject 09 - Fire Safety Improvements, Phase IV (ANL-E)

TEC	Prev.	FY 2002	FY 2003	FY 2004	Outyear	Construction Start/ Completion Dates
8,381	6,351	2,030	0	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.

a Title I and Title II Design funding of $1,100,000 requested under PED Project No. 03-SC-001.
b Title I and Title II Design funding of $545,000 requested under PED Project No. 03-SC-001.

b. Subproject 12 - Site-wide Water Distribution System Upgrade (LBNL)

TEC	Prev.	FY 2002	FY 2003	FY 2004	Outyear	Construction Start/ Completion Dates
8,300	1,000	4,400	2,900	0	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 laboratory 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.

c. Subproject 13 - Groundwater and Surface Water Protection Upgrades (BNL)

TEC	Prev.	FY 2002	FY 2003	FY 2004	Outyear	Construction Start/ Completion Dates
6,050	1,889	2,763	1,398	0	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.

d. Subproject 14 - Fire Protection Systems Upgrades (ORNL)

TEC	Prev.	FY 2002	FY 2003	FY 2004	Outyear	Construction Start/ Completion Dates
5,920	584	3,120	2,216	0	0	3Q 2002 – 4Q 2004

This project will upgrade the 36 year-old fire protection system with improved, more reliable fire alarm capabilities by: replacing deteriorated, obsolete systems; replacing the single 16-inch water main in the east central section of ORNL with a looped system (4,000 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.

e. Subproject 16 – Electrical Systems Modifications, Phase II (BNL)

TEC	Prev.	FY 2002	FY 2003	FY 2004	Outyear	Construction Start/ Completion Dates
6,770	555	3,300	2,915	0	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 24 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.

f. Subproject 17 – Mechanical and Control Systems Upgrade, Phase I (ANL-E)

TEC	Prev.	FY 2002	FY 2003	FY 2004	Outyear	Construction Start/ Completion Dates
9,000	0	803[a]	3,045	5,152	0	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 laboratory exhaust systems could lead to the release of radioactive material). Specifically, this project will: upgrade HVAC systems in Buildings 221 and 362, including heating and cooling coils, fans, filter systems, ductwork, controls, and variable frequency drive fans; upgrade lab exhaust systems in Buildings 202 and 306, including new fans, ductwork, and controls; upgrade corroded drainage systems in Buildings 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

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a Title I and Title II Design funding provided under PED Project No. 02-SC-001.

a Title I and Title II Design funding of $2,000,000 (Subproject 36) requested under PED Project No. 04-SC-001.

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.

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. The National Energy Policy states that fusion power has the long-range potential to serve as an abundant and clean source of energy and recommends that the Department develop fusion. The next frontier in the quest for fusion power is a sustained, burning (or self-heated) plasma, and the Fusion Energy Sciences Advisory Committee (FESAC) has concluded that the fusion program is technically and scientifically ready to proceed with a burning plasma experiment and has recommended joining the ongoing negotiations to construct the international burning plasma experiment, ITER. The National Research Council of the National Academy of Sciences has endorsed this strategy. Based in part on these recommendations and an assessment by the Office of Science of the cost estimate for the construction of ITER, the President has decided that the U.S. should join the ITER negotiations.

Overview:

Fusion science is a subfield of plasma science that deals primarily with studying the fundamental processes taking place in plasmas where the temperature and density approach the conditions needed to allow the nuclei of two low-mass elements, like hydrogen isotopes, to join together, or fuse. When these nuclei fuse, a large amount of energy is released. Fusion science research is organized around the two leading methods of confining the fusion plasma—magnetic, where strong magnetic fields constrain the charged plasma particles, and inertial, where laser or particle beams compress and heat the plasma in very short pulses.

During 1998-1999, the FESAC conducted a major review of the fusion program that culminated in the report, “Priorities and Balance within the Fusion Energy Sciences Program,” dated September 1999. A hallmark of this report is that it presents the first approach to an evenhanded treatment of magnetic fusion science and inertial fusion science. In December 2000, FESAC reviewed a more detailed, independent report, “Report of the Integrated Program Planning Activity for the DOE Fusion Energy Sciences Program,” (IPPA) that reaffirmed that the priorities, balance, and strategic vision laid out in the FESAC 1999 report remain valid. Recommendations in the report of the 2001 National Research Council (NRC) Fusion Assessment Committee review of the quality of the science in the program are consistent with the report. Further, the NRC Fusion Assessment also states “*that the quality of science funded by the United States fusion research program in pursuit of a practical source of power from fusion (the fusion energy goal) is easily on a par with the quality in other leading areas of contemporary physical science*.”

Based on these recent recommendations and assessments, the programmatic goals for the Magnetic Fusion Energy (MFE) and the Inertial Fusion Energy (IFE) parts are designed to address the scientific and technology issues facing fusion energy development.

For magnetic fusion, the scientific and technology issues include:

- the transport of plasma heat from the core outward to the plasma edge and to the material walls as a result of electromagnetic turbulence in the plasma (chaos, turbulence, and transport),

- the stability of the magnetic configuration and its variation in time as the plasma pressure, density, turbulence level, and population of high energy fusion products change (stability, reconnection, and dynamo),
- the role of the colder plasma at the plasma edge and its interaction with both material walls and the hot plasma core (sheaths and boundary layers),
- the interaction of electrons and ions in the plasma with high-power electromagnetic waves injected into the plasma for plasma heating, current drive and control (wave-particle interaction), and
- the development of reliable and economical superconducting magnets, plasma heating and fueling systems, vacuum chamber, and heat extraction systems and materials that can perform satisfactorily in an environment of fusion plasmas and high energy neutrons.

For inertial fusion, the scientific and technology issues include:

- The high-energy-density physics necessary to understand the plasmas produced by intense laser-plasma and beam-plasma interactions,
- the behavior of non-neutral plasmas (such as beams of heavy ions), and
- the acceleration and transport of high-current beams, the development of a target chamber and associated debris clearing, and the fabrication and accurate injection of low-cost targets.

These issues have been codified into four thrusts that characterize the program activities:

- Burning Plasmas, which will include our efforts in support of ITER;
- Fundamental Understanding, which includes Theory and Modeling, as well as general plasma science;
- Configuration Optimization, which includes experiments on advanced tokamaks, magnetic alternates, and inertial fusion concepts, as well as facility operations and enabling R&D; and
- Materials and Technology, which includes fusion specific materials research and fusion nuclear technology research.

Progress in each and all of these thrust areas, in an integrated fashion, is required for ultimate success in achieving a practical fusion energy source.

In light of the President's decision to join the ITER negotiations, many elements of the current fusion program that are broadly applicable to burning plasmas will now be directed more specifically toward the needs of ITER, which will be the focal point of burning plasma fusion research around the world. These elements represent areas of fusion research in which the U.S. has particular strengths, such as theory, modeling and tokamak experimental physics. Longer range technology activities aimed at an eventual commercial fusion reactor will be curtailed to fund new activities related to participating in the ITER project, and to focus on aspects of the present program that most directly support preparations for building and operating ITER: operations and research for the tokamak experimental program (DIII-D and Alcator C-Mod) relevant to burning plasma physics, and ITER-specific computer simulations. The new and redirected elements of the fusion program, and the associated increases in FY 2004 resources, are detailed in the table below. These are resources that would have been allocated differently in this request had the President decided to not enter the negotiations. The U.S. funding commitment to ITER will increase significantly in the outyears as the project moves to construction and eventually to science operations.

Fusion Program Resource Changes in Preparation for ITER

Elements	FY 2004 Resources
DIII-D Experimental Program	$5,000,000
Alcator C-Mod Experimental Program.........................	2,000,000
Fusion Plasma Theory & Computation........................	3,000,000
ITER Preparations	2,000,000
Total	$12,000,000

How We Work:

The primary role of the Fusion Energy Sciences (FES) program governance is the funding, management, and oversight of the program. FES has established an open process for obtaining scientific input for major decisions, such as planning, funding, evaluating and, where necessary, terminating facilities, projects, and research efforts. There are also mechanisms in place for building fusion community consensus and orchestrating international collaborations that are fully integrated with the domestic program. FES is likewise active in promoting effective outreach to and communication with related scientific and technical communities, industrial and government stakeholders, and the public.

Advisory and Consultative Activities:

The Department of Energy uses a variety of external advisory entities to provide input that is used in making informed decisions on programmatic priorities and allocation of resources. The FESAC is a standing committee that provides independent advice to the Director of the Office of Science on complex scientific and technological issues that arise in the planning, implementation, and management of the fusion energy sciences program. The Committee members are drawn from universities, national laboratories, and private firms involved in fusion research. The Director of the Office of Science charges the Committee to provide advice and recommendations on various issues of concern to the fusion energy sciences program. The Committee conducts its business in public meetings, and submits reports containing its advice and recommendations to the Department.

In December 1998, Secretary Richardson asked the Secretary of Energy Advisory Board (SEAB) to form a Task Force on Fusion Energy to conduct a review of the Department's fusion energy technologies, both magnetic and inertial, and to provide recommendations as to the role of these technologies as part of a national fusion energy research program. The final report, "Realizing the Promise of Fusion Energy," August 9, 1999, stated "The scientific progress on fusion has been remarkable. As a result, it is the Task Force's view that the threshold scientific question – namely, whether a fusion system producing sufficient net energy gain to be attractive as a commercial power source can be sustained and controlled – can and will be solved…it is our view that we should pursue fusion energy aggressively."

In December 2002, the National Research Council recommended to the Department that, "…the United States enter ITER negotiations while the strategy for an expanded U.S. fusion program is defined and evaluated."

A variety of other committees and groups provide input to program planning. Ad hoc activities by fusion researchers, such as the 2002 Snowmass meeting, provide a forum for community debate and formation of consensus. The President's Committee of Advisors on Science and Technology (PCAST) has also examined the fusion program on several occasions. As noted, the National Research Council, whose Plasma Physics Committee serves as a continuing connection to the general plasma physics community, recently carried out an assessment of the Department of Energy's Fusion Energy Sciences' strategy for addressing the physics of burning plasmas. In addition, the extensive international collaborations carried out by U.S. fusion researchers provide informal feedback regarding the U.S. program and its role in the international fusion energy effort. These sources of information and advice are integrated with peer reviews of research proposals and when combined with high-level program reviews and assessments provide the basis for prioritizing program directions and allocations of funding.

Program Advisory Committees (PACs) serve an extremely important role in providing guidance to facility directors in the form of program review and advice regarding allocation of facility run time. These PACs are formed primarily from researchers from outside the host facility, including non-U.S. members. They review proposals for research to be carried out on the facility and assess support requirements, and, in conjunction with host research committees, provide peer recommendations regarding priority assignments of facility time. Because of the extensive involvement of researchers from outside the institutions, PACs are also useful in assisting coordination of overall research programs. Interactions among PACs for major facilities assure that complementary experiments are appropriately scheduled and planned.

Facility Operations Reviews:

FES program managers perform quarterly reviews of the progress in operating the major fusion facilities. In addition, a review of each of these major facilities occurs periodically by peers from the other facilities. Further, quarterly reviews of each major project are conducted by the Associate Director for Fusion Energy Sciences with the Federal project manager in the field and other involved staff from both the Department and the performers.

Program Reviews:

The peer review process is used as the primary mechanism for evaluating proposals, assessing progress and quality of work, and for initiating and terminating facilities, projects, and research programs. This policy applies to all university and industry programs funded through grants, national laboratory programs funded through Field Work Proposals (FWPs), and contracts from other performers. Peer review guidelines for FES derive from best practices of government organizations that fund science and technology research and development, such as those documented in the General Accounting Office report, "Federal Research: Peer Review Practices at Federal Science Agencies Vary" (GAO/RCED-99-99, March 1999), as well as more specifically from relevant peer review practices of other programs in the Office of Science.

Merit review in FES is based on peer evaluation of proposals and performance in a formal process using specific criteria and the review and advice of qualified peers. In addition to the review of the scientific quality of the programs provided by the peer review process, FES also reviews the programs for their balance, relevance, and standing in the broader scientific community.

Universities and most industries submit grant proposals to receive funding from FES for their proposed work. The grant review process is governed by the already established SC Merit Review System. DOE national laboratories submit annual field work proposals for funding of both new and ongoing activities. These are subject to peer review according to procedures that are patterned after those given in 10 CFR Part 605 that govern the SC grant program. For the major facilities that FES funds, these extensive reviews are conducted as part of a contract or cooperative agreement renewal, with nominally five-year renewal dates. External peer reviews of laboratory programs are carried on a periodic basis. Grants are typically reviewed every three years.

Planning and Priority Setting:

The FESAC carries out an invaluable role in the fusion energy program by identifying critical scientific issues and providing advice on medium- and long-term goals to address these issues. Most recently, the

FESAC has restated support for conclusions and recommendations first given in the 1999 report "Priorities and Balance within the Fusion Energy Sciences Program."

A program planning activity carried out by the research community, "Report of the Integrated Program Planning Activity for the DOE Fusion Energy Sciences Program," (IPPA) December 2000, provides goals for magnetic and inertial fusion, and a framework and process necessary for the achievement of these goals. The long-term program goals developed in the IPPA are:

- 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.
- Resolve outstanding scientific issues and establish reduced-cost paths to more attractive fusion energy systems by investigating a broad range of innovative magnetic plasma confinement configurations.
- Advance understanding and innovation in high-performance plasmas, optimizing for projected power plant requirements; and participate in a burning plasma experiment.
- Develop enabling technologies needed to advance fusion science; pursue innovative technologies and materials to improve the vision for fusion energy; and apply systems analysis to optimize fusion development.
- Advance the fundamental understanding and predictability of high-energy-density plasmas for IFE, leveraging from the Inertial Confinement Fusion (ICF) target physics work sponsored by the National Nuclear Security Agency (NNSA).
- Develop the science and technology of attractive repetition-rated IFE power systems, leveraging from the ICF work sponsored by NNSA.

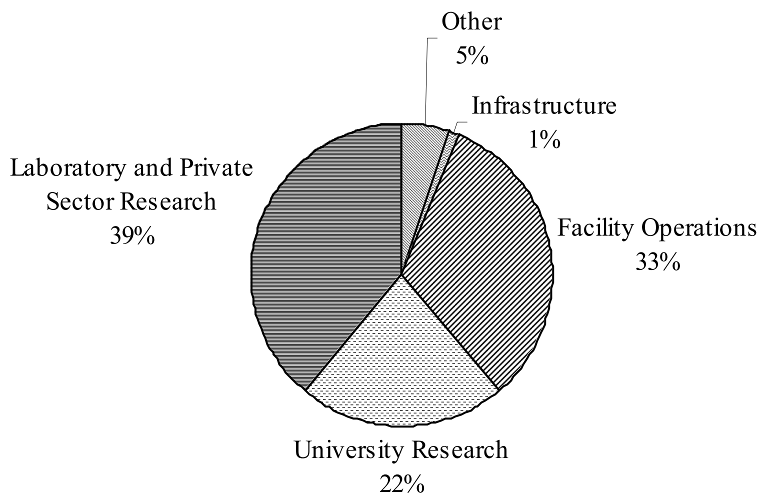
A variety of sources of information and advice, as noted above under the heading "Advisory Activities," are integrated with peer reviews of research proposals and when combined with high-level program reviews and assessments provide the basis for prioritizing program directions and allocations of funding.

How We Spend Our Budget:

The FES budget has three major components: Science, Facility Operations, and Enabling Research and Development. Research efforts are distributed across universities, laboratories, and private sector institutions. In addition to a major research facility at Massachusetts Institute of Technology (MIT), there are several smaller experimental facilities located at universities. There are two other major facilities, located at a national laboratory, and a private sector institution. Enabling Research and Development supports and improves the technical capabilities for ongoing experiments and provides limited long-term development for future fusion power requirements.

The balance of funding levels and priorities underwent overall scrutiny in 1996 by the FESAC when the fusion program focus changed to an increased emphasis on the science underpinnings of fusion research and away from timeline-driven technology development. Subsequent reviews of program quality, relevance, and performance, such as the FESAC review in 1999, "Priorities and Balance Within the Fusion Energy Sciences Program" have made additional adjustments to funding levels for individual programs. As an example, facility operations were planned to be enhanced in FY 2003 relative to FY 2002 and operating time for FY 2004 will remain at the planned FY 2003 level. The research results from these facilities provide a significant addition to the knowledge base required for fusion energy, and therefore it is essential to exploit these facilities to the fullest extent possible. The following chart illustrates the allocation of funding to the major program elements.

Fusion Energy Sciences
Category Breakdown (FY 2004 Request)



Who Does the Research:

The DOE fusion energy sciences program involves over 1,100 researchers and students at more than 70 U.S. academic, federal, and private sector institutions. The program funds research activities at 67 academic and private sector institutions located in 30 states and at 11 DOE and Federal laboratories in 8 states. The three major facilities are operated by the hosting institutions, but are configured with national research teams made up of local scientists and engineers, and researchers from other institutions and universities, as well as foreign collaborators.

University Research:

University researchers continue to be a critically important component of the fusion research program and are responsible for training graduate students. University research is carried out on the full range of scientific and technical topics of importance to fusion energy. University researchers are active participants on the major fusion facilities and one of the major facilities is sited at a university (Alcator C-Mod at MIT). In addition, there are 16 smaller research and technology facilities located at universities, including a basic plasma user science facility at UCLA that is jointly funded by DOE and NSF. There are 5 universities with significant groups of theorists and modelers. About 50 Ph.D. degrees in plasma science and engineering are awarded each year. Over the past three decades, many of these graduates have gone into the industrial sector and brought with them the technical basis for many of the plasma applications found in industry today, including the plasma processing on which today's semiconductor fabrication lines are based.

The university grants program is proposal driven. External scientific peers review proposals submitted in response to announcements of opportunity and funding is competitively awarded according to the guidelines published in 10 CFR Part 605. Support for basic plasma physics is carried out through the NSF/DOE Partnership in Basic Plasma Science and Engineering.

National Laboratory and Private Sector Research:

The Fusion Energy Sciences program supports national laboratory-based fusion research groups at the Princeton Plasma Physics Laboratory, Oak Ridge National Laboratory, Sandia National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Idaho National Engineering and Environmental Laboratory, Argonne National Laboratory, and Los Alamos National Laboratory. In addition, one of the major research facilities is located at and operated by General Atomics in San Diego, California. The laboratory programs are driven by the needs of the Department, and research and development carried out there is tailored to take specific advantage of the facilities and broadly based capabilities found at the laboratories.

Laboratories submit field work proposals for continuation of ongoing or new work. Selected parts of proposals for continuing work are reviewed on a periodic basis, and proposals for new work are peer reviewed. FES program managers review laboratory performance on a yearly basis to examine the quality of their research and to identify needed changes, corrective actions, or redirection of effort.

Program Strategic Performance Goals

SC6-1: Improve 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 and Enabling Technologies subprograms)

Performance Indicator

Eighty percent of all new research projects will be peer reviewed and deemed excellent and relevant, and annually, 30% of all ongoing projects will be subject to peer review with merit evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
	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. (SC6-1)	Conduct feedback control experiments in DIII-D with the new internal control coils to reach plasma operating conditions beyond the limits that can be achieved without the stabilizing effect of a near-by conducting wall. (SC6-1)
	Produce high temperature plasmas with 5 Megawatts of Ion Cyclotron Radio Frequency (ICRF) power for pulse lengths of 0.5 second in Alcator C-Mod. Assess the stability and confinement properties of these plasmas, which would have collisionalities in the same range as that expected for the burning plasma regime. (SC6-1)	Compare energy confinement, H-mode thresholds, and divertor particle dynamics in single-null, double-null, and inner-wall-limited discharges in Alcator C-Mod, establishing limits of divertor power handling for advanced tokamak plasma regimes and requirements for advanced divertors for planned burning plasma tokamaks. (SC6-1)
		Include electron dynamics in turbulent transport simulations and compare the results with experimental results from both U.S. and foreign tokamaks to benchmark the simulation code.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
		(SC6-1)
Use recently upgraded plasma microwave heating system and new sensors on DIII-D to study feedback stabilization of disruptive plasma oscillations. (met goal)		Expand the experiments on stabilization of Neoclassical Tearing Mode instabilities with increased electron cyclotron heating power in DIII-D and compare the results with computational models to benchmark the theories. (SC6-1) Complete detailed design of an advanced, high-power, load tolerant, ion cyclotron radio frequency antenna for C-Mod. (SC6-1)
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) (met goal)	Complete testing of the High-Power Prototype advanced ion-cyclotron radio frequency antenna that will be used at the Joint European Torus.	

SC6-2: Resolve outstanding science/technology issues and explore options for more attractive magnetic and inertial fusion energy systems (Science and Enabling R&D subprograms)

Performance Indicator

Eighty percent of all new research projects will be peer reviewed and deemed excellent and relevant, and annually, 30% of all ongoing projects will be subject to peer review with merit evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Demonstrate innovative techniques for initiating and maintaining current in a spherical torus. (SC6-2) (Goal met)		Assess confinement and stability in NSTX by characterizing high confinement regimes with edge barriers and by obtaining initial results on the avoidance or suppression of plasma pressure limiting modes in high-pressure plasmas. (SC6-2) Integrate elements of initial plasma neutralized beam focus and carry out initial experiments in support of heavy ion beam inertial fusion. (SC6-2) Carry out full voltage beamlet acceleration and determine beamlet characteristic (multibeamlet source configured in FY 2003) for heavy ion beam inertial fusion. (SC6-2)
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. (goal met)	Complete preliminary experimental and modeling investigations of nano-scale thermodynamic, mechanical, and creep-rupture properties of nanocomposited ferritic steels.	Under a cost-shared collaborative program with Japan for irradiation testing of fusion materials in U.S. fission reactors, complete first phase of testing to evaluate the effects of neutron bombardment on the microstructural

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
		evolution, and property changes of candidate fusion materials.
Complete analysis of JET MARK-II inner divertor performance. (goal met)		

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

Performance Indicator

Average operational downtime of FES facilities will not exceed 10% of total time scheduled, and construction and upgrades of facilities will be within 10% of baseline schedule and cost.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Keep deviations in cost and schedule for upgrades and construction of scientific user facilities within 10 percent of project baselines; successfully complete within cost and in a safe manner all TFTR decontamination and decommissioning activities. (goal met)	Keep deviations in cost and schedule for upgrades and construction of scientific user facilities within 10 percent of project baselines; complete the National Compact Stellarator Experiment (NCSX) Preliminary Design. (SC7-6)	Complete the Final Design of the National Compact Stellarator Experiment and begin fabrication.
Keep deviations in weeks of operation for each major facility within 10 percent of the scheduled weeks. (goal not met)	Keep deviations in weeks of operation for each major facility within 10 percent of the scheduled weeks. (SC7-6)	Keep deviations in weeks of operation for each major facility within 10 percent of the scheduled weeks. (SC7-6)

Program Assessment Rating Tool (PART) Assessment

In the PART review, the OMB gave the FES program a perfect score (100) in the "Purpose" section, and a fairly high score (73) in the "Management" section. These scores are attributed to the use of standard management practices in the Office of Science. In the "Planning" section, the low score (56) is attributed by OMB to the FES program's lack of long-term and annual performance measures. Nevertheless, the OMB recognizes that the FES program has made significant strides toward developing such measures despite the problems inherent in predicting and then measuring scientific progress.

Specifically, OMB stated that the FES program delivers projects on cost and schedule, and it receives a significant amount of external expert assessments of its research and program management strategies. However, OMB finds that the program budget is not sufficiently aligned with program goals so that the impact of funding changes on performance is readily known and so that basic research elements can be distinguished from applied research elements.

To address these findings, the program will work to reform its performance measures and goals, understanding the difficulties that basic research program face in attempting to predict future scientific progress. The program will also work to further clarify the relationship between the program's goals and the budget.

Significant Program Shifts

The budget requested for FY 2004 is equal to the FY 2003 Request. The FY 2004 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).

The principal program shifts result from a view that a burning plasma physics experiment is the appropriate next step in the fusion program. Evaluations of domestic technical progress over the past decade have led to an evolution in the program direction to include the burning plasma focus. With the President's decision to join the ITER negotiations to build a burning plasma experimental facility, longer range technology activities will be curtailed to focus on aspects of the present program that most directly support preparations for the realization of the burning plasma device and experiments. In fact, the majority of the existing and proposed program elements already contribute to improving our understanding and future advancement of tokamak science thereby providing a strong base for our future contributions to and ability to benefit from these future experiments.

Whether or not a burning plasma experiment will be realized through the construction and operation of the proposed ITER device will depend on the success of the international negotiations in determining an agreed-upon site for the facility, an agreed-upon financial and procurement arrangement, and satisfactory management and oversight arrangements. In these negotiations, the U.S. will strive for incorporation of its principles of equity, accountability and visibility, which will be an important part of any decision-making process for joining any future construction project. Should the ITER project not proceed to fruition, FESAC has recommended that the U.S. fusion program continue toward a burning plasma experiment, using the FIRE concept which is a modest size burning plasma experiment for which conceptual design studies have been carried out, and seeking partnership from within the international fusion community. Specific burning plasma tasks outlined in this budget proposal are supportive of ITER and would also be supportive of FIRE, as the technical physics issues are similar.

A new program to support fusion science "Centers of Excellence" will be initiated in FY 2004. This new program opportunity responds to recommendations made by the National Research Council in their 2001 assessment of the Fusion Energy Sciences program. This program will enhance the long term development of the human capital that will be needed to carry out a sustained fusion energy program, as well as providing key connections to cross-cutting science efforts at the university level. Proposals will be solicited and peer reviewed to select proposals for funding in FY 2004. It is intended that the role of these centers will be similar to the Science Frontier Centers funded by the National Science Foundation.

AWARDS

- A CalTech student received the 2002 Award for Outstanding Doctoral Dissertation in plasma physics.
- Seven fusion researchers were elected Fellows of the American Physical Society in 2001.
- Four fusion researchers received the 2002 Award for Excellence in Plasma Physics Research from the American Physical Society.
- A young researcher with the IFE program received a Presidential Early Career Award for Scientists and Engineers.

- The TFTR D&D effort at PPPL was honored as 2002 Project of the Year by the Professional Engineers Society of Mercer County (NJ) for use of diamond wire cutting of complex metal vessels.
- A fusion Engineer was honored by the ASME with their Engineering and Technology Management Leadership Award.

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 2002, the FES program supported 365 graduate students and post-doctoral investigators. Of these, 50 students conducted research at the DIII-D tokamak at General Atomics, the Alcator C-Mod tokamak at MIT, or the NSTX at PPPL. A Junior Faculty development program for university plasma physics researchers and the NSF/DOE partnership in basic plasma physics and engineering focus on the academic community and student education.

	FY 2000	FY 2001	FY 2002	FY 2003, est.	FY 2004, est.
# University Grants	177	188	188	185	185
# Permanent PhD's [a]	749	741	731	740	730
# Postdocs	91	99	99	100	100
# Grad Students	246	246	266	270	260
# PhD's awarded	49	49	53	50	50

[a] Permanent PhD's includes faculty, research physicists at universities, and all PhD-level staff at national laboratories.

Scientific Discovery through Advanced Computing (SciDAC)

The Scientific Discovery through Advanced Computing (SciDAC) activity is a set of coordinated investments across all Office of Science mission areas with the goal to achieve breakthrough scientific advances through computer simulation that were impossible using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. By exploiting advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-discipline collaboration among the scientific disciplines, computer scientists and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can fully exploit tera-scale computing and networking resources. The program will bring simulation to a parity level with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate prediction, plasma physics, particle physics, astrophysics and computational chemistry.

Scientific Facilities Utilization

The Fusion Energy Sciences request includes funds 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.

The total number of weeks of operation at all of the major fusion facilities is shown in the following table.	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004
Maximum weeks	75	75	75	75	75
Scheduled weeks	54	44	34	63	63
Unscheduled weeks of Downtime	7%	0%	6%	TBD	TBD

In addition to the operation of the major fusion facilities, several Major Item of Equipment projects are supported in the fusion program. Milestones for these projects are shown in the following table.

FY 2000	FY 2001	FY 2002	FY 2003	FY 2004
Completed NSTX Neutral Beam.				
			Complete NCSX preliminary design. Start NCSX project.	Complete final design of NCSX and begin fabrication.
Started C-Mod Lower Hybrid Upgrade Project.			Complete C-Mod Lower Hybrid Upgrade Project.	

Funding Profile

(dollars in thousands)

	FY 2002 Comparable Appropriation	FY 2003 Request	FY 2004 Request	$ Change	% Change
Fusion Energy Sciences					
Science....................................	134,307	142,565	144,670	+2,105	+1.5%
Facility Operations	70,803	78,653	87,726	+9,073	+11.5%
Enabling R&D..........................	35,990	36,092	24,914	-11,178	-31.0%
Subtotal, Fusion Energy Sciences..	241,100	257,310	257,310	0	--
Adjustment.....................................	0	0	0	0	--
Total, Fusion Energy Sciences	241,100[b][c]	257,310	257,310	0	--

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

[b] Excludes $139,000 for the FY 2002 rescission contained in section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to Terrorist attacks on the United States.
[c] Excludes $5,888,000 which was transferred to the SBIR program and $353,000 which was transferred to the STTR program.

Funding By Site[a]

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	7,799	7,308	3,765	-3,543	-48.5%
Sandia National Laboratories	3,178	3,213	2,786	-427	-13.3%
Total, Albuquerque Operations Office	10,977	10,521	6,551	-3,970	-37.7%
Chicago Operations Office					
Argonne National Laboratory	1,662	1,522	1,192	-330	-21.7%
Princeton Plasma Physics Laboratory	69,607	63,576	70,563	+6,987	+11.0%
Chicago Operations Office	44,586	49,317	50,140	+823	+1.7%
Total, Chicago Operations Office	115,855	114,415	121,895	+7,480	+6.5%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	2,356	2,392	1,823	-569	-23.8%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	5,952	5,799	5,718	-81	-1.4%
Lawrence Livermore National Laboratory	14,510	14,411	13,408	-1,003	-7.0%
Oakland Operations Office	69,595	73,779	69,926	-3,853	-5.2%
Total, Oakland Operations Office	90,057	93,989	89,052	-4,937	-5.3%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science & Education	347	808	888	+80	+9.9%
Oak Ridge National Laboratory	19,454	19,258	18,693	-565	-2.9%
Oak Ridge Operations Office	0	0	0	0	--
Total, Oak Ridge Operations Office	19,801	20,066	19,581	-485	-2.4%
Richland Operations Office					
Pacific Northwest National Laboratory	1,415	1,556	1,440	-116	-7.5%
Richland Operations Office	0	0	0	0	--
Total, Richland Operations Office	1,415	1,556	1,440	-116	-7.5%

[a] On December 20, 2002, the National Nuclear Security Administration (NNSA) disestablished the Albuquerque, Oakland, and Nevada Operations Offices, renamed existing area offices as site offices, established a new Nevada Site Office, and established a single NNSA Service Center to be located in Albuquerque. Other aspects of the NNSA organizational changes will be phased in and consolidation of the Service Center in Albuquerque will be completed by September 30, 2004. For budget display purposes, DOE is displaying non-NNSA budgets by site in the traditional pre-NNSA organizational format.

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Savannah River Operations Office					
Savannah River Laboratory	50	49	45	-4	-8.2%
Washington Headquarters	589	14,322	16,923	+2,601	+18.2%
Total, Fusion Energy Sciences	241,100[bc]	257,310	257,310	0	--

[b] Excludes $139,000 for the FY 2002 rescission contained in section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to Terrorist attacks on the United States.
[c] Excludes $5,888,000 which was transferred to the SBIR program and $353,000 which was transferred to the STTR program.

Site Description

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700-acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. Argonne's Fusion Energy Sciences program contributes to a variety of 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 magnetic 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. In FY 2003, INEEL will complete a small tritium laboratory (Safety and Tritium Applied Research Facility).

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 accelerator 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 from and completion of the stabilization of the Tritium Systems Test Assembly facility prior to turning the facility over to the Office of Environmental Management for Decontamination and Decommissioning at the end of FY 2003.

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, is a major partner with PPPL on 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 has completed 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 Measures

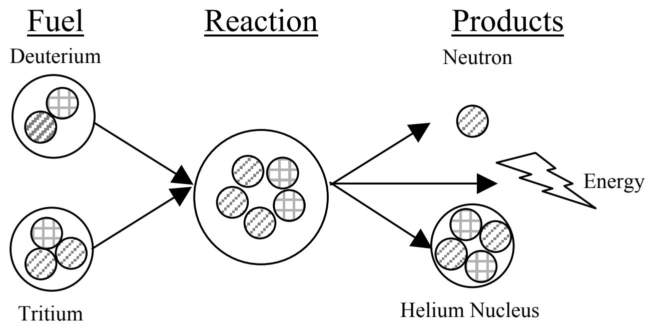
The Science subprogram supports the quest for fusion power by fostering fundamental research in plasma science aimed at a predictive understanding of plasmas in a broad range of plasma confinement configurations. There are two basic approaches to confining a fusion plasma and insulating it from its much colder surroundings—magnetic and inertial confinement. In the former, carefully engineered magnetic fields isolate the plasma from the walls of the surrounding vacuum chamber, while in the latter, a pellet of fusion fuel is compressed and heated so quickly that there is no time for the heat to escape. There has been great progress in plasma science during the past three decades, in both magnetic and inertial confinement, and today the world is at the threshold of a major advance in fusion power development--the study of burning plasmas, in which the self-heating from fusion reactions dominates the plasma behavior.

Plasmas, the fourth state of matter, comprise over 99% of the visible universe and are rich in complex, collective phenomena. During the past decade there has been considerable progress in our fundamental understanding of key individual phenomena in fusion plasmas, such as transport driven by micro-turbulence, and macroscopic equilibrium and stability of magnetically confined plasmas. Over the next five years the Science subprogram will continue to advance the understanding of plasmas through an integrated program of experiments, theory, and simulation as outlined in the ***Integrated Program Planning Activity for the Fusion Energy Sciences Program*** prepared for FES and reviewed by the Fusion Energy Sciences Advisory Committee. This integrated research program will focus on well-defined plasma scientific issues including turbulent transport, macroscopic stability, wave particle interactions, multiphase interfaces, hydrodynamic stability, implosion dynamics, and heavy-ion beam transport and focusing. We expect this research program to yield new methods for sustaining and controlling high temperature, high-density plasmas, which will have a major impact on a burning plasma experiment, such as ITER, and to benefit from ignition experiments on the NNSA-sponsored National Ignition Facility (NIF).

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 Junior Faculty development grants for members of university plasma physics faculties, will continue to contribute to this objective. A new “Centers of Excellence in Fusion Science” program will also foster fundamental understanding and connections to related sciences.

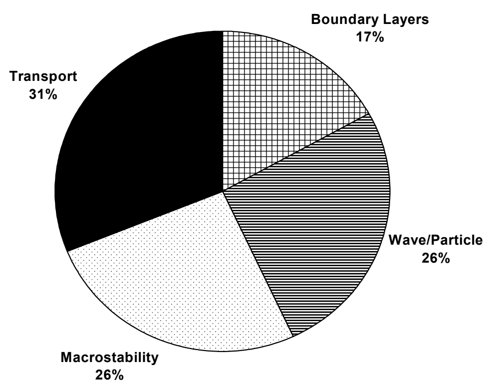
Plasma science includes not only plasma physics but also physical phenomena in a much wider class of ionized matter, in which atomic, molecular, radiation-transport, excitation, and ionization processes are important. These phenomena can play significant roles in partially ionized media and in the interaction 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, industrial processing, and national security.

Fusion science, a major sub-field of plasma science, is focused primarily on describing the fundamental processes taking place in plasmas where the peak temperatures are greater than 100 million degrees Celsius and densities great enough that hydrogenic nuclei collide and 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 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 fields is likely to be required for ultimate success in achieving a practical fusion energy source.



The total funding spent on MFE in FY 2002 is split roughly as shown to address major scientific issues.

For Inertial Fusion Energy (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.

SCIENCE ACCOMPLISHMENTS

Research funded by the Fusion Energy Sciences program in FY 2002 produced major scientific results over a wide range of activities. Selected accomplishments that address scientific issues for fusion and long-term fusion goals include:

- Studies of feedback stabilization of disruptive plasma oscillation were successfully carried out in DIII-D in FY 2002, using the recently acquired electron cyclotron heating (ECH) power. Up to 4.0

MW of ECH power was deposited in selected regions of the plasma, using steerable ECH antennae, to drive additional plasma current. These currents alter the conditions for detrimental plasma oscillations and stabilize them to avoid disruptions. The stabilization of different modes of oscillations has been demonstrated, raising the performance of the plasma and extending its pulse length. (SC6-1 FY 2002 Target)

- NSTX has successfully demonstrated innovative techniques for initiating and maintaining current in a spherical torus. The device initiated plasmas using Coaxial Helicity Injection and maintained high ratios of plasma pressure to applied magnetic pressure for increased durations by raising current drive while reducing induction. A number of these plasmas were operating in the High-Confinement-Mode (H-mode) lasting essentially the flat-top duration of the plasma current. (SC6-1 FY 2002 Target)
- Improved modeling of macroscopic stability has been achieved. Improvements in extended magnetohydrodynamic codes enabled by the Scientific Discovery through Advanced Computing initiative have made it possible to simulate the dynamics of NSTX plasmas that have strong sheared flows.
- There are new results in the area of transport and turbulence in tokamaks. New measurements using high speed cameras on C-Mod, NSTX and DII-D have shown the presence of “blobs” of high density plasma being formed and moving outward from the region of good confinement in all three machines. Movies showing the time evolution of this process have been made. These “blobs” may account for the bigger part of the turbulent transfer across the magnetic field. Together with other direct measurements, this work is now providing some insight into the cause of the density limits observed in tokamaks.
- With the availability of the new, high-performance computer at the National Energy Research Scientific Computing Center, it is now possible to simulate the turbulence in tokamaks approaching the size of the International Thermonuclear Experimental Reactor (ITER). Simulations performed in the past year indicate that the transport caused by the plasma turbulence initially increases with the size of the plasma, but then levels off at a constant value. This is a favorable result for reactor-scale tokamaks like ITER and provides increased confidence that they will achieve their desired fusion energy gain.
- One major concern for tokamaks is that tokamak discharges might prematurely terminate (disrupt) when the plasma pressure or density exceeds their limits, and cause excessive current or heat loads on the tokamak components. On DIII-D, such disruptions have been successfully terminated by injecting high-pressure noble gas into the plasma, thereby, avoiding high-energy runaway electrons, unwanted plasma currents in the vessel, and excessive heat load on divertor target plates.
- Innovative confinement concepts have also shown improvements in stability, turbulence and transport. New results have been achieved in some of these concepts that will provide the basis in the future for further development as fusion power sources. As an example, current profile modification experiments in the Madison Symmetric Torus (MST) at the University of Wisconsin have greatly reduced magnetic fluctuations, increasing the energy confinement time by a factor of 10 above the usual empirical scaling for reversed-field pinches (RFPs).
- Inertial fusion energy is a non-magnetically confined approach to fusion energy in which energy-producing targets are compressed and ignited by external beams. For heavy ion beam drivers, producing, transporting, and focusing the beams are the main technical challenges and are one of the

main IFE program goals. Recent experiments at LBNL have achieved record currents in the high current experiment (HCX) using both electrostatic and magnetic focusing elements. The results from these measurements provide an important database for validating beam transport calculations.

Subprogram Goals

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.

Resolve outstanding scientific issues and establish reduced-cost paths to more attractive fusion energy systems by investigating a broad range of innovative magnetic and inertial plasma confinement configurations.

Advance understanding and innovation in high-performance magnetically confined plasmas, optimizing for projected power plant requirements and participate in an international burning plasma experiment.

Advance the fundamental understanding and predictability of high energy density plasmas for IFE, leveraging from the Inertial Confinement Fusion (ICF) target physics work sponsored by the National Nuclear Security Agency (NNSA).

Performance Indicators

(1) Fraction of all new research projects that are peer reviewed and deemed excellent and relevant; target 80%.

(2) Fraction of all ongoing projects subject to peer review with merit evaluation; target 30% per year.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Show that stability in a tokamak can be affected by the interaction of microwaves with electrons in the core of the plasma. Result: achieved on DIII-D.	Maintain high performance in DIII-D by controlling plasma instabilities with microwaves.	Use higher power radio frequency and microwave systems to extend the range of validity for the negative central shear mode of advanced tokamak operation on the DIII-D facility.
	Explore operating regime of the newly discovered “quiescent double barrier” mode on DIII-D.	Develop improved physics understanding of the “quiescent double barrier” mode on DIII-D and evaluate its impact on the operational range of advanced tokamaks.
Apply new diagnostics including high speed cameras to increase understanding of transport at the edge of tokamaks. Result: achieved on C-Mod and NSTX.	Demonstrate the role of self-driven currents in edge instabilities in DIII-D using the new edge current diagnostics.	Carry out studies of transport in the edge of C-MOD plasmas for high densities near density limits.
Using improved magnetohydrodynamic codes developed under SciDAC to analyze NSTX modes with toroidal totation to explain changes in plasma profiles. Result: achieved on NSTX.	Measure and analyze the dispersion of heat flux on plasma facing components under conditions of high heating power in NSTX.	Assess confinement and stability in NSTX by characterizing high confinement regimes with edge barriers and by obtaining initial results on the avoidance or suppression of plasma pressure plasmas.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Demonstrate enhanced energy confinement times in a reversed-field-pinch by use of current modification. Result: achieved transiently on MST at the University of Wisconsin.	Study the effects of magnetic fluctuations in high temperature plasmas on magnetic reconnection and dynamo.	Continue the study of the magnetic dynamo, which is intrinsic to the reversed-field –pinch and is of interest to several other fields of non-fusion plasma science.
Bring on line 3 new experimental facilities for heavy ion inertial fusion research (high current experiment, source test stand and plasma system for beam focusing) and begin initial operation of each. Result: Each of the facilities was completed and brought into operation.	Conduct beam transport analysis for full current beams in HCX to provide a data base for "end to end" beam simulations.	Evaluate the effects of stray electrons on heavy ion beam instabilities by comparing results from the high current experiment (HCX) with calculations of beam transport through HCX.
	Carry out detailed comparisons of experimental measurements of turbulence in tokamak facilities with calculations made with codes enhanced under SciDAC.	Explore MHD equilibrium and stability in stellarators using linear and nonlinear global stability codes, including free-boundary and finite larmor radius effects. Compare code calculations with experimental results from international stellarators in preparation for the operation of NCSX.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Tokamak Experimental Research	45,479	48,609	46,340	-2,269	-4.7%
Alternative Concept Experimental Research	52,328	50,913	52,169	+1,256	+2.5%
Theory	27,628	27,608	28,508	+900	+3.3%
General Plasma Science	8,872	9,060	11,050	+1,990	+22.0%
SBIR/STTR	0	6,375	6,603	+228	+3.6%
Total, Science	134,307	142,565	144,670	+2,105	+1.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Tokamak Experimental Research	**45,479**	**48,609**	**46,340**

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 facilities abroad aimed at establishing an international database of Tokamak experimental results. In association with the International Tokamak Physics Activity, both DIII-D and Alcator C-Mod will increase their efforts on joint experiments with other major facilities in Europe and Japan in support of ITER-relevant physics issues.

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 and microwave current drive and the interface between the plasma edge and the material walls of the confinement vessel by means of a "magnetic divertor." Achieving high performance regimes for longer pulse duration, approaching the steady state, will require simultaneous advances in all of the scientific issues listed above.

▪ **DIII-D Research**	**23,747**	**22,733**	**23,329**

The DIII-D tokamak is the largest magnetic fusion facility in the United States. DIII-D provides for considerable experimental flexibility and has extensive diagnostic instrumentation to measure what is happening in a high temperature plasma. It also has unique capabilities to shape the plasma, which, in turn, affects 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 the 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.)

The DIII-D experimental program contributes to all four key Magnetic Fusion Energy (MFE) fusion topical science areas—energy transport, stability, plasma-wave interactions, and boundary physics, and various thrust areas that integrate across topical areas to support the goal of achieving a burning plasma. The level of effort for most physics research topics in FY 2004 remains essentially flat from FY 2003, however, *there will be an increased effort on joint research topics in support of burning plasma physics, specifically for ITER. The research will elucidate the effects of plasma edge instabilities and high pressure in various plasma confinement regimes, extending the duration of stable plasma operation, and helping build cross-machine data bases using dimensionless parameter ("wind tunnel") techniques among other topics.*

The program will also continue the investigation of the scientific basis for optimization of the tokamak approach to fusion energy production. This research includes investigation of different modes of operation of fusion plasmas in the so-called Advanced Tokamak (AT) regime for enhancing the attractiveness of tokamak plasmas for energy production. In particular, the experimental program will aim at accomplishing the following three related research goals in FY 2004: 1) demonstrate the technical benefits of operating AT plasmas with a normalized beta (a measure of plasma pressure) value above the "standard" value, made possible by feedback control of new internal wall stabilization coils installed in FY 2003. The initial experiments in FY 2003 with these coils will set direction of the experiments in FY 2004. 2) Extend the "Negative Central Shear" mode of AT research to higher performance and long pulse plasmas using the 6 MW Ion Cyclotron Range Frequency (ICRF) system, and the 6 MW Electron Cyclotron Heating (ECH) system. The refurbishment and commissioning of the ICRF system, which was built about 4 years ago, will start in FY 2003, and it will be available for these experiments in FY 2004. This system will provide additional electron heating capability and improve the current drive provided by the ECH system. 3) Investigate further the physics of the Quiescent Double Barrier (QDB) AT regime, which was discovered in DIII-D 3 years ago. The QDB regime is attractive for steady-state operation of AT plasmas because of the absence of periodic heat pulses that impinge on divertor target plates. The activities in all these three areas are interrelated, and they will improve the physics basis and demonstration of a long-pulse, high-performance AT for energy production purposes.

	FY 2002	FY 2003	FY 2004
▪ **Alcator C-Mod Research**	**7,479**	**8,464**	**8,458**

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 high power densities.

By virtue of these characteristics, Alcator C-Mod 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, high density burning plasma physics tokamaks. Burning plasmas can be achieved for short pulses in a low cost tokamak by trading high magnetic field for large size (and cost). Alcator C-Mod has made significant contributions to the world fusion program in the areas of plasma heating, stability, and confinement in high field tokamaks, which are important integrating issues related to ignition and burning of a fusion plasma. In FY 2004 the C-Mod research effort is approximately level with that of FY 2003. However, *resources will be focused on ITER relevant topics such as understanding the physics of the plasma edge in the presence of large heat flows, measuring the effects of and mitigating disruptions in the plasma, controlling the current density profile for better stability, and helping build cross-machine data bases using dimensionless parameter ("wind tunnel") techniques*.

Research will also continue to examine the physics of the plasma edge, power and particle exhaust from the plasma, mechanisms of self-generation of plasma flows, and the characteristics of the Advanced Tokamak modes achieved when currents are driven by radio and microwaves. It will also focus on studying transport in the plasma edge at high densities and in relation to the plasma density limit. A diagnostic neutral beam will further improve visualization of turbulence in the edge and core of high density plasmas, and beam enabled diagnostics will shed light on the plasma physics of temperature and density profile pedestals whose features are now thought to predict future machine

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

behavior. Active MHD spectroscopy is a novel method for sensing the onset of instability and will also be implemented in FY 2004. This diagnostic may well revolutionize the way a plasma discharge is feedback controlled to avoid disruptions. Compact high field tokamak regimes and operation scenarios required for ignition in compact devices will be further explored. The new lower hybrid (microwave) current drive system will be in operation, and experiments will begin using it for control of the current density profile.

	FY 2002	FY 2003	FY 2004
▪ **International Collaborations, Education and Other**	**7,158**	**10,255**	**7,540**

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.

International collaboration will continue on unique tokamaks abroad. However, *the United States will reduce the international program activities in FY 2004 and focus on joint International Tokamak Physics Activity (ITPA) with Japan, Europe, and Russia to enhance collaboration on physics issues related to tokamak burning plasmas.* In FY 2004, the remaining direct collaboration with international 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 the relocation of personnel and facilities to a new location within ORNL has been transferred to the facility operations subprogram. Funding for educational activities in FY 2004 will support research at historically black colleges and universities, graduate and postgraduate fellowships in fusion science and technology, summer internships for undergraduates, and outreach efforts related to fusion science and technology.

	FY 2002	FY 2003	FY 2004
▪ **Experimental Plasma Research (Tokamaks)**.........................	**7,095**	**7,157**	**7,013**

Funding provided in this category, for FY 2004, will continue to support research on innovative tokamak experiments at universities and the development of diagnostic instruments.

The Electric Tokamak (ET) at UCLA will explore several new approaches to toroidal magnetic confinement using radio waves to drive plasma rotation and in order to achieve a very high plasma pressure relative to the applied magnetic field, which in turn will produce a deep magnetic well for good plasma confinement. Complementing the advanced tokamak research on DIII-D and Alcator C-Mod is the exploratory work on two university tokamaks. This has the prospect of leading to more efficient use of magnetized volume and steady-state plasma stability, with associated attractiveness in eventual fusion power applications. The goal of the High Beta Tokamak (HBT) at Columbia University is to demonstrate the feasibility of stabilizing instabilities in a high pressure tokamak plasma using a combination of a close-fitting conducting wall, plasma rotation, and active feedback. This work is closely coordinated with the DIII-D program, and promising results have already been achieved on DIII-D.

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 energy 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 2004 supports research that will enhance our understanding of critical plasma phenomena and the means of affecting these phenomena to improve energy and particle confinement in tokamaks and innovative confinement machines. *The funding will also support development of diagnostic systems related to the processes associated with burning plasmas, on U.S. and foreign facilities.* Currently supported programs were the highest ranked proposals submitted to a competitive peer review in FY 2002.

	FY 2002	FY 2003	FY 2004
Alternative Concept Experimental Research	**52,328**	**50,913**	**52,169**

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 operating in FY 2000. Like DIII-D and Alcator C-Mod, NSTX is also operated as a national scientific user facility.

	FY 2002	FY 2003	FY 2004
▪ **NSTX Research**	**12,780**	**13,696**	**15,951**

NSTX is one of the world's two largest embodiments of the spherical torus confinement concept. 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. Plasmas in spherical torii 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 torii 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. An associated issue for spherical torus configurations is the challenge of driving plasma current via radio-frequency waves or biased electrodes. Such current drive techniques are essential to achieving sustained operation of a spherical torus.

The spherical torus plasma, as in all high beta plasmas, is uniquely characterized by high velocity fast ions and with a large radius of gyration relative to plasma size that could potentially lead to new plasma behaviors of interest. In FY 2004, increased funding will allow enhanced participations by national team members in several areas. Comparison of experimental results with theory will

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

contribute to the scientific understanding of these effects needed to consider future experiments with similar energetic ion properties. Several new diagnostics that will become operational will be used on NSTX. Using these new diagnostics, assessment of long wavelength turbulence in the plasma core in a range of operating scenarios will also be undertaken. Additionally, measurement of current profile modifications from the applications of RF techniques, neutral beam injection, and the bootstrap effect will be pursued with measurement techniques suitable for low magnetic field devices. Finally, new measurement techniques using beams of energetic atoms and lasers will be employed to assess changes in the profile of the plasma current induced by radio-frequency waves, injected energetic neutral particles, and changes in the plasma pressure profile to determine how best to sustain large currents in spherical torii.

- **Experimental Plasma Research (Alternatives)** **25,955** **23,443** **22,721**

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 both the NCSX and QPS novel compact stellarator designs.

The goals of this work are to: a) find new innovative confinement schemes that have advantages when compared to the tokamak; b) find new innovative ways of increasing the plasma performance of advanced confinement schemes like the tokamak, stellarator, or reversed field pinch; and c) find innovative ways to study in an isolated manner key issues of plasma behavior, such as reconnection or turbulence. All these efforts are to be done on small, low cost experimental devices.

The Innovative Confinement Concept (ICC) development program is a broad-based activity with researchers located at national laboratories, universities, and industry. Because of the small size of the experiments and the use of the latest technologies, these small-scale experiments provide excellent places to train students and post-docs, and develop the next generation of fusion scientists who will need to explore the next frontier of fusion research, burning plasma.

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. Another design, the Quasi-Poloidal Stellarator (QPS), using an even more radical approach, is being pursued at ORNL. This design is based on a different symmetry to achieve an even more compact configuration. Both approaches will strengthen U.S. involvement in the much larger world stellarator program.

The magnetized target fusion program (funded by the FES program) at LANL and the Air Force Research Laboratory will study the possibility that a field reversed configuration plasma can be compressed to multi-keV temperatures using fast liner compression technology developed by NNSA's Defense Programs.

The key to success in this program is to be continually generating new innovative ideas. In order to foster a vigorous breeding ground for these kinds of ideas, each year approximately 1/3 of the concepts will be competitively peer reviewed. This review will be used to weed out the concepts that have not been able to follow through with their initial innovative ideas, and to find new innovative ideas that can be pursued in small experiments. The review will affect the innovative confinement concepts program in FY 2004. It is anticipated that there will be some changes in the program.

	FY 2002	FY 2003	FY 2004
▪ **Inertial Fusion Energy Experiments**......................................	**13,593**	**13,774**	**13,497**

An entirely different set of science explorations is being carried out in the area of inertial fusion. 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. In assessments of IFE carried out by several committees and study groups in the past, heavy ions were recommended as the optimum driver for inertial fusion energy, with lasers as possible alternatives. Based on these assessments, heavy ions define the focus for the FES program. However, there have been recent advances in energy producing target design and high average power laser technology. In the NNSA inertial confinement program, there is a dual use program for high average power lasers that has inertial fusion energy relevance. Within the FES program, there are some elements that support innovation in IFE (fast ignitor science, for example) with relevance to laser driven IFE and there are commonalities in technology areas in target chambers and target technologies that are coordinated between FES and NNSA. 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.

The inertial fusion energy program is focused 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.

Heavy ion accelerators continue to be the leading IFE driver candidate. The physics of intense heavy ion beams (multiply charged Bismuth, for example) and other non-neutral plasmas are 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.

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. In FY 2004, the High Current Experiment (HCX) will do experiments to simulate ion bunch control with electrostatic and magnetic focusing elements. The dynamics of stray electrons will be studied, and results used to compare with beam simulation calculations. The neutralized focus experiments using the facility jointly developed by PPPL and LBNL will be completed. New ion beamlet acceleration tests will be completed to obtain beamlet characteristics. Physics experiments carried out on NNSA-funded facilities including (in the future) the National Ignition Facility (NIF) will provide high energy density physics data to be used in the design of targets for IFE experiments. Experiments on 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.

	FY 2002	FY 2003	FY 2004
Theory	**27,628**	**27,608**	**28,508**

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 facilities, 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 controlled.

The theory and modeling program is a broad-based program with researchers located at national laboratories, universities, and industry. Institutional diversity is a strength of the program, since theorists at different types of institutions play different roles in the program. Theorists in larger groups, which are mainly at national laboratories and industry, generally support major experiments, work on large problems requiring a team effort, or tackle complex issues requiring a multidisciplinary teams while those at universities generally support smaller, innovative experiments or work on more fundamental problems in plasma physics.

The theory program is composed of four elements—tokamak theory, alternate concept theory, generic theory, and advanced computation. The main thrust of the work in tokamak theory is aimed at

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

developing a predictive understanding of advanced tokamak operating modes and burning plasmas, both of which are important to ITER. 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.

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.

In FY 2004 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 the preparations for a burning plasma experiment, a set of innovative national experiments, and fruitful collaboration on major international facilities. Through the middle of FY 2004, computational efforts will be focused on comparison of experimental results with turbulence calculations, that include kinetic electrons, the inclusion of the plasma's self-generated currents, and flows 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 the basis for developing a more comprehensive predictive understanding of fusion plasmas, which will be of great value in planning for a burning plasma experimental program in ITER. *In addition, the FES program will initiate a new "Centers of Excellence in Fusion Science" program in FY 2004. This action responds to a recommendation from the NRC assessment report. It is anticipated that no more than 2 centers will be funded.* Continuation of this effort in the future could lead to a more comprehensive capability that would pave the way to improved utilization of ITER and enhanced scientific understanding from ITER.

General Plasma Science...	**8,872**	**9,060**	**11,050**

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

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

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 2004, the program will continue to fund proposals that have been peer reviewed. *In addition, Fusion Energy Sciences will initiate a new "Centers of Excellence in Fusion Science" program in FY 2004. This action responds to a recommendation from the NRC assessment report. It is anticipated that no more than 2 centers will be funded.* 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 continue to share the cost of funding plasma physics frontier science centers funded by NSF.

	FY 2002	FY 2003	FY 2004
SBIR/STTR	**0**	**6,375**	**6,603**

The FY 2002, FY 2003 and FY 2004 amounts are the estimated requirements for the continuation of these programs.

	FY 2002	FY 2003	FY 2004
Total, Science	**134,307**	**142,565**	**144,670**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Tokamak Experimental Research	
▪ Funding for DIII-D research in the Science subprogram has increased marginally to cover research preparations and data analysis needs.	+596
▪ A slight decrease in funding for the Alcator C-Mod.	-6
▪ Funding for support of studies using International Facilities is reduced and redirected to higher priority FES activities.	-1,194
▪ Funding for the relocation of personnel and facilities to a new location at ORNL has been transferred to the Facilities Operations subprogram.	-1,521
▪ Funding for Experimental Plasma Research (Tokamaks) has been marginally reduced to cover higher priority activities.	-144
Total, Tokamak Experimental Research	-2,269
Alternative Concept Experimental Research	
▪ Funding for NSTX research is increased to provide for additional data analysis and research in support of operations	+2,255
▪ Funding for Experimental Plasma Research is reduced and redirected to higher priority FES activities.	-722
▪ Funding for IFE is reduced and redirected to higher priority FES activities. The rate of progress in ion source development will be slowed.	-277
Total, Alternative Concept Experimental Research	+1,256

	FY 2004 vs. FY 2003 ($000)
Theory	
▪ Funding is increased for studies of innovative concepts and burning plasma physics.	+900
General Plasma Science	
▪ Funding is increased for initiation of "Centers of Excellence in Fusion Science", with 1-2 new centers.	+1,990
SBIR/STTR	
▪ Support for SBIR/STTR is provided at the mandated level.	+228
Total Funding Change, Science	**+2,105**

Facility Operations

Mission Supporting Goals and Measures

The Facility Operations subprogram manages the operation of the major fusion research facilities and the fabrication of new projects to the highest standards of overall performance, using merit evaluation and independent peer review. The 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, fabrication of new projects 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 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 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 provides funds for operating and maintenance personnel, electric power, expendable supplies, replacement parts, system modifications and facility enhancements. In FY 2004, funding is requested to operate the major fusion facilities at a level of 84% of full utilization.

Funding is also provided for the continuation of the National Compact Stellarator Experiment (NCSX) Major Item of Equipment project at PPPL. In FY 2004, the project will be in its second year, following the FY 2003 request for project start, and FY 2004 funding will support the final design activities and initial procurements of hardware.

Funding is also provided for ITER transitional activities, in which U.S. scientists and engineers will be involved in various technical activities that support both ITER negotiations for a construction project as well as preparations for eventual project construction.

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. Funding is also provided for the move of ORNL personnel and facilities to a new location at ORNL.

FACILITY OPERATIONS ACCOMPLISHMENTS

In FY 2002, 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 completed the majority of the installation of a new system of Resistive Wall Mode stabilization coils to provide for increased control of the fusion plasma in real-time. Also, 5 Electron Cyclotron Heating power systems were operated simultaneously into the DIII-D plasma, and this will enable higher performance plasma operation in the future.

- Upgrades to improve the performance capability of NSTX were completed successfully. A real-time digital control system was added to provide precision control of the coil systems and enable improved control of the fusion plasma. The vacuum vessel bakeout temperature was upgraded to 350 degrees, thereby providing for the creation of cleaner plasma in a shorter time than for the current system. The Coaxial Helical Injection system for injecting fuel particles was installed on NSTX, and initial operation to form a plasma was successful.
- In accordance with previous advice from technical experts to periodically inspect the Alcator C-Mod coil system, MIT personnel disassembled the device, performed the inspection, and confirmed coil system integrity. The device was re-assembled and returned to full operation. The C-Mod Lower Hybrid heating system remains on track for completion in FY 2003. A new diagnostic neutral beam was added to improve plasma characterization.
- The TFTR decontamination and decommissioning (D&D) activities at PPPL were completed successfully within cost and schedule.

Subprogram Goals

Operate major fusion facilities for specified number of weeks.

For facility upgrades and new projects accomplish cost and schedule targets**.**

Performance Indicator

Average operational downtime of FES facilities will not exceed 10% of total time scheduled and construction and upgrades of facilities will be within 10% of baseline schedule.

Annual Performance Results and Targets

FY 2002 Results		FY 2003 Request Targets		FY 2004 Targets	
Operate DIII-D	12 weeks vs. 14 weeks planned	Operate DIII-D	21 weeks	Operate DIII-D	21 weeks
Operate Alcator C-Mod	8 weeks	Operate Alcator C-Mod	21 weeks	Operate Alcator C-Mod	21 weeks
Operate NSTX	12 weeks	Operate NSTX	21 weeks	Operate NSTX	21 weeks
For TFTR, completed the project on cost and on schedule.					
		For NCSX, complete Preliminary Design.		For NCSX, complete the Final Design and begin hardware procurement.	
		For Alcator C-Mod, complete Lower Hybrid project.			

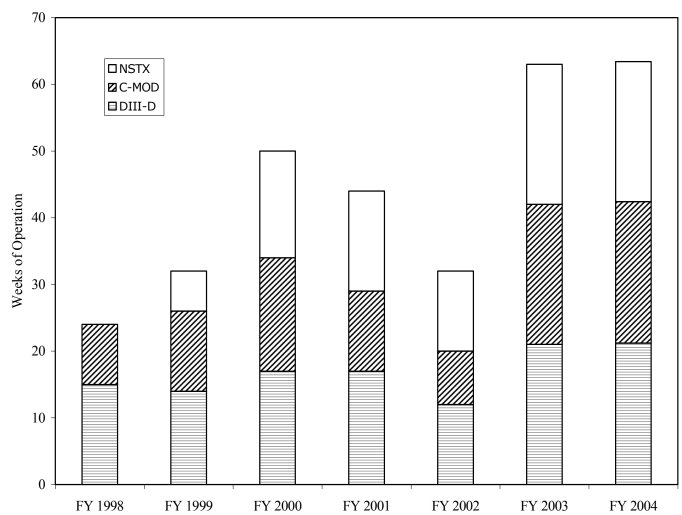
The table below summarizes the longer-term history of operation of the major fusion facilities.

Weeks of Fusion Facility Operation

(Weeks of Operations)

	FY 2002 Actual	FY 2003 Request	FY 2004
DIII-D	12	21	21
Alcator C-Mod	8	21	21
NSTX	12	21	21
Total	32	63	63

Recent operating history of major fusion experimental facilities



Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
TFTR	15,794	0	0	0	--
DIII-D	27,184	32,909	33,336	+427	+1.3%
Alcator C-Mod	10,095	13,789	14,249	+460	+3.3%
NSTX	15,241	19,446	19,237	-209	-1.1%
NCSX	0	11,026	15,921	+4,895	+44.4%
ITER	0	0	1,990	+1,990	--
GPP/GPE/Other	2,489	1,483	2,993	+1,510	+101.8%
Total, Facility Operations	70,803	78,653	87,726	+9,073	+11.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
TFTR	**15,794**	**0**	**0**

The TFTR Decontamination and Decommissioning (D&D) activity was completed in FY 2002.

DIII-D	**27,184**	**32,909**	**33,336**

Provide support for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems. The improvements include replacement of two microwave heating tubes. In FY 2004, these funds support 21 weeks of single shift plasma operation during which time essential scientific research will be performed as described in the science subprogram.

Alcator C-Mod	**10,095**	**13,789**	**14,249**

Provide support for operation, maintenance, and minor machine improvements. The improvements include additional diagnostics and preparations for heating system additions. In FY 2004, these funds support 21 weeks of single shift plasma operation during which time essential scientific research will be performed as described in the science subprogram.

NSTX	**15,241**	**19,446**	**19,237**

Provide support for operation, maintenance, and improvement of the NSTX facility and installation of planned diagnostic upgrades. In FY 2004, these funds support 21 weeks of single shift plasma operation. The FY 2004 budget will continue to support preventive maintenance and purchase of critical spare parts to minimize down time and improve facility reliability. In addition, new hardware will be installed to optimize research output. This includes an improved resonant field control system, a prototype microwave scattering system to measure high-k fluctuations, an imaging diagnostic for edge helium emission, and an array of absolutely calibrated x-ray detectors for Lyman-alpha emission from the divertor.

NCSX	**0**	**11,026**	**15,921**

Funding in the amount of $15,921,000 is requested for the continuation of the National Compact Stellarator Experiment (NCSX) Major Item of Equipment, which was initiated in FY 2003 and consists of the design and fabrication of a compact stellarator proof-of-principle class experiment. These funds will allow completion of the final design of most systems and the procurement of long lead-time items. 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 NCSX design will allow experiments that compare confinement and stability in tokamak and stellarator configurations. The preliminary total estimated cost (TEC) of NCSX is $73,500,000, with completion scheduled for FY 2007. When the preliminary design is completed at the end of FY 2003, the cost and schedule baseline will be established.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
ITER	**0**	**0**	**1,990**

Funding in the amount of $1,990,000 is provided to initiate ITER transitional activities such as licensing, project management, preparation of final specifications and system integration. U.S. personnel will participate in these activities in preparation for eventual project construction.

General Plant Projects/General Purpose Equipment/Other	**2,489**	**1,483**	**2,993**

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. Funds also provide for the move of ORNL personnel and facilities to a new location at ORNL.

Total, Facility Operations	**70,803**	**78,653**	**87,726**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
DIII-D	
▪ Funding is approximately the same. The number of weeks of operation, 21, is unchanged from the FY 2003 request and the supporting activities such as maintenance, enhancement and repair are also unchanged.	+427
Alcator C-Mod	
▪ Funding is approximately the same. The number of weeks of operation, 21, is unchanged from the FY 2003 request and the supporting activities such as maintenance, enhancement and repair are also unchanged.	+460
NSTX	
▪ Funding is approximately the same. The number of weeks of operation, 21, is unchanged from the FY 2003 request. However, there is a modest reduction in facility enhancements in FY 2004 relative to FY 2003..	-209
NCSX	
▪ Funding is increased consistent with project needs to design and procure hardware for the NCSX project at PPPL. The level of design activity on key components, such as the magnets and vacuum vessel, will increase in order to keep the projection of schedule	+4,895
ITER	
▪ Funding is increased due to the start of this new activity which provides for preparatory ITER activities.	+1,990

	FY 2004 vs. FY 2003 ($000)
GPP/GPE/Other	
▪ Funding is increased to provide necessary improvements in the PPPL infrastructure and to move ORNL fusion personnel and facilities to a new location at ORNL.	+1,510
Total Funding Change, Facility Operations	**+9,073**

Enabling R&D

Mission Supporting Goals and Measures

The Enabling R&D subprogram develops the cutting edge technologies that enable both U.S. and international fusion research facilities to achieve their goals.

The Engineering Research element addresses the breadth and diversity of domestic interests in enabling R&D for magnetic fusion systems as well as international collaborations that support the mission and objectives of the FES program. The activities in this element focus on critical technology needs for enabling both current and future U.S. plasma experiments to achieve their research goals and full performance potential in a safe manner, with emphasis on plasma heating, fueling, and surface protection technologies. While much of the effort is focused on current devices, a significant amount of the research is specifically focused on future burning plasma experiments. The R&D effort on these technologies involves evolutionary development advances in present day capabilities that will make it possible to enter new plasma experiment regimes, such as burning plasmas. These nearer-term technology advancements also enable international technology collaborations that allow the United States to access plasma experimental conditions not available domestically. This element includes investigation of scientific issues for innovative technology concepts that could make revolutionary changes in the way that plasma experiments are conducted, such as liquid surface approaches to control of plasma particle density and temperature, microwave generators with tunable frequencies and steerable launchers for fine control over plasma heating and current drive, magnet technology which could improve confinement. This element also includes safety research which allows us to conduct both current and future experiments in an environmentally sound and safe manner.

Another activity is conceptual 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. In the past, longer term basic research on future magnetic and inertial fusion energy chamber concepts were conducted in this element, however, those programs are now being terminated and the funding for this category will be used for an orderly closeout of all activities.

The Materials Research element focuses on the key science issues of materials for practical and environmentally attractive uses in fusion research and future facilities. This element continues to strengthen its modeling and theory activities, which makes it more effective at using and leveraging the substantial work on nanosystems and computational materials science being funded by BES, as well as more capable of contributing to broader materials research in niche areas of materials science. Through a variety of cost-shared international collaborations, this element conducts irradiation testing of candidate fusion materials in the simulated fusion environments of fission reactors to provide data for validating and guiding the development of models for the effects of neutron bombardment on the microstructural evolution, damage accumulation, and property changes of fusion materials. This collaborative work supports both near-term fusion devices, such as a burning plasma experiment, as well as other future fusion experimental facilities. In addition, such activities support the long-term goal of developing experimentally validated predictive and analytical tools that can lead the way to nano-scale design of advanced fusion materials with superior performance and lifetime.

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.

In FY 2002, a series of retrospective peer reviews by independent experts was completed of the scientific and technical quality, progress, and relevance of each element of the Enabling R&D subprogram. Summary reports of reviewer panel members' findings and recommendations, along with community action plans to address the most significant findings and recommendations, can be viewed on the Virtual Laboratory for Technology website at http://vlt.ucsd.edu/peer.html. Although most elements of this subprogram were determined to rank highly in most aspects of quality, progress, and relevance, steps have been taken to make improvements in all areas of concern to the reviewers.

ENABLING R&D ACCOMPLISHMENTS

A number of technological advances were made in FY 2002. Examples include:

- Scientists at Sandia National Laboratory achieved record levels of performance in proposed high heat flux components for future burning plasma experiments. The ability to reliably remove high levels of surface heat deposited by burning plasmas, while not deteriorating rapidly or contaminating the plasma with impurities, is a major technology issue for the plasma facing components. The levels of surface heat flux expected on some plasma facing components can reach as high as those observed in rocket nozzles. In testing done on water-cooled tungsten-copper mockups of proposed high heat flux components, the mockups sustained some of the highest levels of heat flux expected in burning plasma experiments for thousands of heating cycles without damage. This testing demonstrated the viability of this concept, with future research aimed at extending performance limits and testing tolerances to off-normal events.
- Scientists at Princeton Plasma Physics Laboratory, University of California San Diego, and Sandia National Laboratory continued to observe encouraging results in 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 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 Laboratory, University of California Los Angeles, University of California Santa Barbara, Princeton University, and Lawrence Livermore National Laboratory continued to make significant progress in developing models for micro-structural 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 Oak Ridge National Laboratory and Princeton Plasma Physics Laboratory completed the design and fabrication of the prototype of a high power radio frequency antenna that will enable increased levels of plasma heating. The prototype, which is to be tested in FY 2003, will validate the

design, performance, and fabrication techniques of antennae to be built for use in the Joint European Torus plasma experiment. These antennae will provide the world's most powerful radio frequency plasma heating capability, and will permit investigation into advanced modes of fusion-relevant plasma performance.

Subprogram Goals

Develop the cutting edge technologies that enable FES research facilities to achieve their scientific goals and allow the U.S. to enter into international collaborations that enable access to plasma experiment conditions not available domestically.

Advance the science base for innovative materials to establish the technical feasibility of fusion energy and to enable fusion to reach its full potential as an environmentally and economically attractive energy source.

Performance Indicator

Percentage of milestones met for installing components developed by the Enabling R&D program on existing experimental devices.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Complete design and fabrication of at least one cutting edge technology that enables a FES research facility to achieve its scientific goals and/or allows the U.S. to enter into an international collaboration enabling access to plasma experiment conditions not available domestically. (goal met)	Initiate installation and begin testing of at least one cutting edge enabling technology.	Complete testing of at least one cutting edge enabling technology.
Complete preliminary investigation of at least one innovative technology that can create a more attractive vision of fusion energy systems. (goal met)	Design and install a liquid lithium limiter on CDX-U for testing as an advanced particle control/high heat flux handling system.	Complete closeout activities of all work on MFE and IFE chamber technologies.
Establish preliminary science base for at least one innovative low activation, high performance structural material that can validate the technical feasibility of fusion energy and enable fusion to reach its full potential as an attractive energy source. (goal met)	Complete initial experimental and modeling investigations of at least one innovative low activation, high performance structural material.	Identify elemental composition and fabrication methods through nanoscience methods to improve the performance and lifetime of at least one low activation structural material system.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Engineering Research	28,814	28,454	17,314	-11,140	-39.2%
Materials Research	7,176	7,638	7,600	-38	-0.5%
Total, Enabling R&D	35,990	36,092	24,914	-11,178	-31.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Engineering Research	**28,814**	**28,454**	**17,314**
▪ **Plasma Technology**	**12,023**	**12,092**	**13,986**

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 ITER.* Nearer-term experiment support efforts will be oriented toward plasma facing components and plasma heating and fueling technologies. Building on the testing in FY 2003 of a prototype radio frequency antenna—that will enable JET to build a powerful plasma heating device workable under rapidly changing plasma parameters—the detailed design of a similar high performance antenna will be completed for C-Mod in FY 2004. Based on the experimental research and design assessment in FY 2003 for a first-generation liquid metal system that allows lithium to interact directly with the plasma in a controlled way, the preliminary design of a lithium module for future deployment in NSTX will be initiated in FY 2004. This new plasma-facing component technology has the potential to revolutionize the approach to plasma particle density and edge temperature control in plasma experiments. Development and testing will continue for an advanced 1.5 million watt microwave generator that will efficiently heat plasmas to high temperatures, with 60% efficiency to be demonstrated in tests planned for FY 2004. Following completion in FY 2003 of the Safety and Tritium Applied Research (STAR) Facility at INEEL, material science experiments will be fully underway at STAR under a cost-sharing collaboration with Japan to resolve key issues of tritium behavior in different materials proposed to be used in fusion systems. *Additional funding will be provided to allow the STAR facility to undertake safety research for both current devices and* for ITER. 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.

	FY 2002	FY 2003	FY 2004
▪ **Fusion Technology**	**10,563**	**10,906**	**1,338**

Fusion Technology efforts such as liquid metal analysis and experiments, which were focused on basic research on future MFE and IFE chamber concepts, are being terminated to provide resources for higher priority and nearer term activities. Funding for this category will be used for an orderly closeout of all activities. With the completion in FY 2003 of the tritium inventory reduction and stabilization at TSTA, TSTA transfer to EM will have been completed by the start of FY 2004.

	FY 2002	FY 2003	FY 2004
▪ **Advanced Design**	**6,228**	**5,456**	**1,990**

Funding for this element will focus on design studies of systems for next-step plasma science experiment options. The FIRE design effort will be completed in FY 2003. Systems science studies to assess both the research needs underlying achievement of the safety, economics, and environmental characteristics and the prospects of possible advanced magnetic confinement concepts will be conducted in an iterative fashion with the experimental community.

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		
Materials Research	**7,176**	**7,638**	**7,600**

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. Investigations of experimentally-validated models that can predict and quantify embrittlement produced by fusion environments of body centered cubic metals, the crystal structure of the most promising structural materials for fusion chambers, is expected to lead in FY 2004 to a Master Curve model that is based on successful approaches taken in other material science research programs. Also during FY 2004, the first phase of a cost-shared collaborative program with Japan for irradiation testing of fusion materials in a U.S. fission reactor (HFIR) will be completed, providing key data to evaluate the effects of neutron bombardment on the microstructural evolution, damage accumulation, and property changes of fusion materials that could be used in next step devices. In addition, results will be available on testing of nanocomposited ferritic steels with alloy compositions and fabrication techniques designed through nanoscience methods to operate at high temperatures without significant deformation by creep mechanisms.

	FY 2002	FY 2003	FY 2004
Total, Enabling R&D	**35,990**	**36,092**	**24,914**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Engineering Research	
▪ Plasma Technology funding is increased due to the move of the safety and tritium research program to this category.	+1,894
▪ Funding for TSTA is terminated following completion in FY 2003 of work to clean up the facility prior to turning it over to the Office of Environmental Management for Decontamination and Decommissioning. Funding for other fusion technologies activities is decreased to meet higher priority budget needs in facility operations in preparation for participation in ITER.	-9,568
▪ Advanced Design funding is reduced in order to meet higher priority budget needs in facility operations in preparation for participation in ITER.	-3,466
Total, Engineering Research	-11,140
Materials Research	
▪ Funding is reduced due to completion of a task on irradiation testing in the HFIR reactor in FY 2003.	-38
Total Funding Change, Enabling R&D	**-11,178**

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
General Plant Projects	2,149	995	1,415	+420	+42.2%
Capital Equipment	7,411	15,774	20,089	+4,315	+27.4%
Total, Capital Operating Expenses	9,560	16,769	21,504	+4,735	+28.2%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp- riations	FY 2002	FY 2003	FY 2004	Accept- ance Date
DIII-D Upgrade	27,225	27,203	22	0	0	FY 2001
Alcator C-Mod LH Modification	5,200	2,966	1,505	1,019[a]	0	FY 2003
NCSX	73,500[b]	0	0	11,026	15,921	FY 2007
Total, Major Items of Equipment		30,169	1,527	12,045	15,921	

[a] During FY 2003 execution, this funding will be reduced to $729,000 to accommodate funding acceleration in FY 2002 and to retain the TEC of $5,200,000. The $1,019,000 presently in this column is the FY 2003 President's Request funding amount.

[b] The preliminary TEC has increased from $69,000,000 to $73,500,000 based on the recently completed conceptual design activities, which demonstrated that more contingency funds are needed for fabricating the highest risk components. The estimates will be improved as the preliminary design activities are completed in FY 2003 at which time the cost baseline will be set.

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 Computer Security Program Plan (CSPP) or other appropriate plan. SC's Integrated Safeguards and Security Management (ISSM) strategy encompasses a graded approach to safeguards and security. ISSM will promote individual ownership and essential security performance at all Office of Science facilities. ISSM is not a standard, nor is it a new program; rather it is a set of principles and a formal methodology that is the basis of integrated management of security in all work practices at all levels by all DOE/SC employees. ISSM is intended to assist in weaving together existing programs into a "system" that has as its foundation personal responsibility, and including security in all work practices. This approach will enable each facility to design varying degrees of protection commensurate with the risks and consequences described with their facility-specific threat scenarios.

The following is a brief description of the types 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 classified or "Official Use Only" (OUO) 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 classified and OUO 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, environment, safety and health 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.

Significant Program Shifts

In FY 2004 there are no significant program shifts. In FY 2002 increased program emphasis was due to the heightened security demands from the September 11, 2001 incident.

Funding Profile

(dollars in thousands)

	FY 2002 Comparable Appropriation	FY 2003 Request	FY 2004 Request	$ Change	% Change
Science Safeguards and Security					
Protective Forces	23,085	22,345	22,345	0	0.0%
Security Systems	8,314	4,532	4,532	0	0.0%
Information Security	1,023	1,000	1,000	0	0.0%
Cyber Security	10,265	11,714	11,714	0	0.0%
Personnel Security	1,831	2,576	2,576	0	0.0%
Material Control and Accountability	2,031	2,676	2,676	0	0.0%
Program Management	3,681	3,284	3,284	0	0.0%
Subtotal, Science Safeguards and Security	50,230	48,127	48,127	0	0.0%
Less Security Charge for Reimbursable Work	-4,460	-4,383	-4,383	0	0.0%
Total, Science Safeguards and Security	45,770[ab]	43,744	43,744	0	0.0%

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 $2,650,000 transferred from Basic Energy Sciences ($2,600,000) and Biological and Environmental Research ($50,000) for a FY 2002 reprogramming for safeguards and security.
[b] Excludes $29,000 for the FY 2002 rescission contained in section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to terrorist attacks on the United States.

Funding By Site[a]

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Chicago Operations Office					
Ames Laboratory	397	409	409	0	0.0%
Argonne National Laboratory	7,679	7,809	7,809	0	0.0%
Brookhaven National Laboratory	10,916	10,970	10,970	0	0.0%
Fermi National Accelerator Laboratory	2,684	2,837	2,837	0	0.0%
Princeton Plasma Physics Laboratory	1,828	1,855	1,855	0	0.0%
Total, Chicago Operations Office	23,504	23,880	23,880	0	0.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	4,706	4,753	4,753	0	0.0%
Stanford Linear Accelerator Center	2,150	2,207	2,207	0	0.0%
Total, Oakland Operations Office	6,856	6,960	6,960	0	0.0%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education	1,081	1,254	1,254	0	0.0%
Oak Ridge National Laboratory	9,509	7,913	7,913	0	0.0%
Thomas Jefferson National Accelerator Facility	927	972	972	0	0.0%
Oak Ridge Operations Office	8,322	7,148	7,148	0	0.0%
Total, Oak Ridge Operations Office	19,839	17,287	17,287	0	0.0%
Washington Headquarters	31	0	0	0	0.0%
Subtotal, Science Safeguards and Security	50,230	48,127	48,127	0	0.0%
Less Security Charge for Reimbursable Work	-4,460	-4,383	-4,383	0	0.0%
Total, Science Safeguards and Security	45,770[bc]	43,744	43,744	0	0.0%

[a] On December 20, 2002, the National Nuclear Security Administration (NNSA) disestablished the Albuquerque, Oakland, and Nevada Operations Offices, renamed existing area offices as site offices, established a new Nevada Site Office, and established a single NNSA Service Center to be located in Albuquerque. Other aspects of the NNSA organizational changes will be phased in and consolidation of the Service Center in Albuquerque will be completed by September 30, 2004. For budget display purposes, DOE is displaying non-NNSA budgets by site in the traditional pre-NNSA organizational format.

[b] Includes $2,650,000 transferred from Basic Energy Sciences ($2,600,000) and Biological and Environmental Research ($50,000) for a FY 2002 reprogramming for safeguards and security.

[c] Excludes $29,000 for the FY 2002 rescission contained in section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to terrorist attacks on the United States.

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 98% success rate for preventing unauthorized intrusions into SC Cyber Systems that process "Official Use Only" (OUO) information, with a long term goal of striving for 100% in the outyears.

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Ames Laboratory	**397**	**409**	**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. Reimbursable work is included in the numbers above; the amount for FY 2004 is $26,000.

Argonne National Laboratory	**7,679**	**7,809**	**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. Reimbursable work is included in the numbers above; the amount for FY 2004 is $388,000.

Brookhaven National Laboratory	**10,916**	**10,970**	**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. Reimbursable work is included in the numbers above; the amount for FY 2004 is $806,000.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Fermi National Accelerator Laboratory	**2,684**	**2,837**	**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.

Lawrence Berkeley National Laboratory	**4,706**	**4,753**	**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. Reimbursable work is included in the numbers above; the amount for FY 2004 is $830,000.

Oak Ridge Institute for Science and Education	**1,081**	**1,254**	**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. Reimbursable work is included in the numbers above; the amount for FY 2004 is $319,000.

Oak Ridge National Laboratory	**9,509**	**7,913**	**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. Reimbursable work is included in the numbers above; the amount for FY 2004 is $1,945,000.

Oak Ridge Operations Office	**8,322**	**7,148**	**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, Building 3019 ($6,013,000). Other small activities include security systems, information security, and personnel security.

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		
Princeton Plasma Physics Laboratory	**1,828**	**1,855**	**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. Reimbursable work is included in the numbers above; the amount for FY 2004 is $54,000.

Stanford Linear Accelerator Center	**2,150**	**2,207**	**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. Reimbursable work is included in the numbers above; the amount for FY 2004 is $15,000.

Thomas Jefferson National Accelerator Facility	**927**	**972**	**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.

All Other	**31**	**0**	**0**

This funding provides for program management needs for the Office of Science in FY 2002.

Subtotal, Science Safeguards and Security	**50,230**	**48,127**	**48,127**
Less Security Charge for Reimbursable Work	**-4,460**	**-4,383**	**-4,383**
Total, Science Safeguards and Security	**45,770**	**43,744**	**43,744**

Subprogram Goals

Performance will be measured by a 98% success rate for preventing unauthorized intrusions into SC Cyber Systems that process Official Use Only information, with a long term goal of striving for 100% in the outyears.

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 Official Use Only 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.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Establish baseline of actual intrusions.	95% success rate for preventing unauthorized intrusions into SC Cyber Systems that process official use only information commensurate with risk from FY 2002 baseline.	98% success rate for preventing unauthorized intrusions into SC Cyber Systems that process official use only information commensurate with risk from FY 2003 baseline.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
	This will be accomplished by: (1) Reviewing Computer Incident Advisory Capability (CIAC) reports for SC sites that process Official Use Only 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.	This will be accomplished by: (1) Reviewing Computer Incident Advisory Capability (CIAC) reports for SC sites that process Official Use Only information to establish a current baseline number of unauthorized intrusions into SC Cyber Systems; (2) Achieving, maintaining, and verifying that incidents remain below 2% 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.

Detailed Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Ames Laboratory					
Protective Forces	149	143	143	0	0.0%
Security Systems	60	24	24	0	0.0%
Cyber Security	97	148	148	0	0.0%
Personnel Security	34	42	42	0	0.0%
Material Control and Accountability	7	7	7	0	0.0%
Program Management	50	45	45	0	0.0%
Total, Ames Laboratory	397	409	409	0	0.0%
Argonne National Laboratory					
Protective Forces	2,963	3,209	3,209	0	0.0%
Security Systems	715	455	455	0	0.0%
Information Security	236	211	211	0	0.0%
Cyber Security	1,705	1,888	1,888	0	0.0%
Personnel Security	865	904	904	0	0.0%
Material Control and Accountability	815	796	796	0	0.0%
Program Management	380	346	346	0	0.0%
Total, Argonne National Laboratory	7,679	7,809	7,809	0	0.0%
Brookhaven National Laboratory					
Protective Forces	6,083	6,146	6,146	0	0.0%
Security Systems	931	577	577	0	0.0%
Information Security	126	131	131	0	0.0%
Cyber Security	2,285	2,470	2,470	0	0.0%
Personnel Security	38	49	49	0	0.0%
Material Control and Accountability	482	742	742	0	0.0%
Program Management	971	855	855	0	0.0%
Total, Brookhaven National Laboratory	10,916	10,970	10,970	0	0.0%
Fermi National Accelerator Laboratory					
Protective Forces	1,447	1,700	1,700	0	0.0%
Security Systems	417	246	246	0	0.0%
Cyber Security	653	780	780	0	0.0%
Material Control and Accountability	66	49	49	0	0.0%
Program Management	101	62	62	0	0.0%
Total, Fermi National Accelerator Laboratory	2,684	2,837	2,837	0	0.0%

(dollars in thousands)	FY 2002	FY 2003	FY 2004	$ Change	% Change
Lawrence Berkeley National Laboratory					
Protective Forces	1,297	1,392	1,392	0	0.0%
Security Systems	1,113	942	942	0	0.0%
Cyber Security	1,802	2,019	2,019	0	0.0%
Personnel Security	32	11	11	0	0.0%
Material Control and Accountability	22	38	38	0	0.0%
Program Management	440	351	351	0	0.0%
Total, Lawrence Berkeley National Laboratory	4,706	4,753	4,753	0	0.0%
Oak Ridge Institute for Science and Education					
Protective Forces	165	288	288	0	0.0%
Security Systems	153	100	100	0	0.0%
Information Security	122	139	139	0	0.0%
Cyber Security	332	420	420	0	0.0%
Personnel Security	91	108	108	0	0.0%
Program Management	218	199	199	0	0.0%
Total, Oak Ridge Institute for Science and Education	1,081	1,254	1,254	0	0.0%
Oak Ridge National Laboratory					
Security Systems	4,636	1,790	1,790	0	0.0%
Information Security	246	304	304	0	0.0%
Cyber Security	2,154	2,305	2,305	0	0.0%
Personnel Security	528	1,182	1,182	0	0.0%
Material Control and Accountability	639	1,044	1,044	0	0.0%
Program Management	1,306	1,288	1,288	0	0.0%
Total, Oak Ridge National Laboratory	9,509	7,913	7,913	0	0.0%
Oak Ridge Operations Office					
Protective Forces	7,700	6,541	6,541	0	0.0%
Security Systems	86	112	112	0	0.0%
Information Security	293	215	215	0	0.0%
Personnel Security	243	280	280	0	0.0%
Total, Oak Ridge Operations Office	8,322	7,148	7,148	0	0.0%
Princeton Plasma Physics Laboratory					
Protective Forces	1,137	905	905	0	0.0%
Security Systems	35	113	113	0	0.0%
Cyber Security	559	775	775	0	0.0%
Program Management	97	62	62	0	0.0%
Total, Princeton Plasma Physics Laboratory	1,828	1,855	1,855	0	0.0%

(dollars in thousands)	FY 2002	FY 2003	FY 2004	$ Change	% Change
Stanford Linear Accelerator Center					
Protective Forces	1,742	1,606	1,606	0	0.0%
Security Systems	0	0	0	0	0.0%
Cyber Security	408	601	601	0	0.0%
Program Management	0	0	0	0	0.0%
Total, Stanford Linear Accelerator Center	2,150	2,207	2,207	0	0.0%
Thomas Jefferson National Accelerator Facility					
Protective Forces	402	415	415	0	0.0%
Security Systems	168	173	173	0	0.0%
Cyber Security	270	308	308	0	0.0%
Program Management	87	76	76	0	0.0%
Total, Thomas Jefferson National Accelerator Facility	927	972	972	0	0.0%
All Other					
Program Management	31	0	0	0	0.0%
Subtotal, Science Safeguards and Security	50,230	48,127	48,127	0	0.0%
Less Security Charge for Reimbursable Work	-4,460	-4,383	-4,383	0	0.0%
Total, Science Safeguards and Security	45,770	43,744	43,744	0	0.0%

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
No Funding Changes.	

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
General Plant Projects	2,821	0	0	0	0.0%
Capital Equipment	95	0	0	0	0.0%
Total, Capital Operating Expenses	2,916	0	0	0	0.0%

Science Program Direction

Program Mission

The mission of Science Program Direction (SCPD) is to provide a Federal workforce, skilled and highly motivated, to manage and support a broad set of scientific disciplines, research portfolio, programs, projects, and facilities under the Office of Science's (SC) leadership.

SCPD consists of four subprograms: Program Direction, Field Operations, Technical Information Management (TIM) and Energy Research Analyses (ERA). Beginning in FY 2003, Program Direction and Field Operations were realigned to include all functions performed in the SC Field complex in the Field Operations subprogram. With this change, the Program Direction subprogram continues to be 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 Field Operations subprogram is the centralized funding source for the Federal workforce within the field complex responsible for providing best-in-class business, administrative, and specialized technical support across the entire SC enterprise and to other DOE programs. The TIM subprogram collects, preserves, and disseminates the scientific and technical information (STI) of the DOE for use by the DOE, the scientific community, academia, U.S. industry, and the public to expand the knowledge base of science and technology. The ERA subprogram provides the capabilities needed to evaluate and communicate the scientific excellence, relevance, and performance of SC basic research programs, provide analysis of key scientific and technical issues, and document the societal outcomes of SC research.

Significant Program Shifts

- Beginning in FY 2002, and continuing into FY 2004, SC is conducting an organizational and workforce restructuring project to address fundamental issues and functions within the Office. The Office of Science (SC) Restructuring Project will realign its Headquarters and Field structure and streamline and improve the management and implementation of its programs by reducing layers of management, streamlining decision making processes, clarifying lines of authority, and making more efficient use of resources. This project reflects the changes envisioned by the President's Management Agenda (PMA) and directly supports the PMA objective to manage government programs more economically and effectively. Full implementation of the SC realignment is expected to take place during FY 2004.
- During the on-going restructuring, SC will continue to work toward rightsizing the number of full-time equivalents (FTEs) by the end of FY 2005. The FY 2003 President's Budget Request for SC Program Direction proposed to reduce the number of FTEs from 1,045 in FY 2002 to 840 in FY 2003, with corresponding reductions in program direction funding. However, the workforce restructuring project was not completed, and a reduction of this magnitude (20 percent) would have resulted in involuntary reductions-in-force (IRIFs), and substantial reduction in SC's ability to carry out its mission. In order to avoid IRIFs, SC utilized uncosted funding in the amount of $6,999,000 and delayed certain activities to offset the funding shortage in FY 2003. SC had further planned to use buyout authority to voluntarily reduce staffing, but this authority was not granted to the Department, and it was therefore necessary to revise the number of FY 2003 FTEs from 840 to 965. The FY 2004 request is also based on 965 FTEs to permit continued support for current staff (and to fill critical scientific positions), while allowing the restructuring project to be completed in FY 2004.

The restructuring will result in more informed decisions on the number of FTEs and types of position required to fulfill SC's programmatic and administration responsibilities.

- In FY 2003, the House Energy and Water Development (EWD) Appropriations Subcommittee proposed transferring TIM (from the Energy Supply appropriation) and ERA into SCPD as new subprograms. Since TIM is currently managed by SC, this transfer of funding from the Energy Supply appropriation aligns all SC program resources under the Science appropriation.
- In order to provide enhanced emphasis on education activities, Science Education, a former subprogram within SCPD, is budgeted in the newly established Workforce Development for Teachers and Scientists program, beginning in FY 2004.

Funding Profile

(dollars in thousands)

	FY 2002 Comparable Appropriation	FY 2003 Request	FY 2004 Request	$ Change	% Change
Science Program Direction					
Program Direction	51,345	55,984	58,217	+2,233	+4.0%
Science Education	0	0	0	0	--
Field Operations	89,591	72,403	83,802	+11,399	+15.7%
Technical Information Management	7,563	7,925	7,774	-151	-1.9%
Energy Research Analyses	968	1,020	1,020	0	--
Total, Science Program Direction	149,467 [a,b]	137,332 [a,b,c]	150,813	+13,481	+9.8%
Additional net budget authority to cover the cost of fully accruing retirement (non-add)	(7,479)	(6,060)	(6,567)	(+507)	(+8.4%)
Staffing (FTEs)					
Headquarters (FTEs)	261	284	284	0	--
Field Operations (FTEs)	591	609	609	0	--
Technical Information Management (FTEs)	75	72	72	0	--
Total, FTEs	927 [d]	965 [d]	965	0	--

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] Includes TIM and ERA as proposed by the House EWD Appropriations Subcommittee to be effective in FY 2003.

[b] Excludes $4,460,000 in FY 2002 and $5,460,000 in FY 2003 for Science Education transferred to new Workforce Development for Teachers and Scientists program in FY 2004.

[c] In order to avoid IRIFs, SC utilized uncosted funding in the amount of $6,999,000 and delayed certain activities to offset the funding shortage in FY 2003.

[d] Revised estimate based on reprioritization of FY 2002 and FY 2003 activity to avoid IRIFs in both fiscal years. Also includes transfer of 72 FTEs for Technical Information Management (TIM) effective in FY 2003 consistent with the House EWD Subcommittee proposal. The FY 2002 Comparable Appropriation in the FY 2003 President's Request was 1,045 FTEs (293 FTEs in Headquarters, 676 FTEs in the Field, and 76 FTEs for TIM). The FY 2003 President's Request was 840 FTEs (299 FTEs in Headquarters, 467 FTEs in the Field, and 74 for TIM).

Funding by Site

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Albuquerque Operations Office[a]					
Sandia National Laboratory/Albuquerque	155	100	100	0	--
Chicago Operations Office					
Chicago Operations Office	36,148	28,035	34,056	+6,021	+21.5%
Oak Ridge Operations Office					
Oak Ridge National Laboratory	60	0	0	0	--
Oak Ridge Institute for Science and Education	24	55	55	0	--
Office of Scientific and Technical Information	7,563	7,925	7,774	-151	-1.9%
Oak Ridge Operations Office	50,756	41,817	47,225	+5,408	+12.9%
Total, Oak Ridge Operations Office	58,403	49,797	55,054	+5,257	+10.6%
Oakland Operations Office[a]					
Lawrence Berkeley National Laboratory	0	50	50	0	--
Berkeley and Stanford Site Offices	3,000	2,861	2,831	-30	-1.0%
Total, Oakland Operations Office	3,000	2,911	2,881	-30	-1.0%
Richland Operations Office					
Pacific Northwest National Laboratory	414	465	465	0	--
Washington Headquarters	51,347	56,024	58,257	+2,233	+4.0%
Total, Science Program Direction	149,467[bc]	137,332[bc]	150,813	+13,481	+9.8%
Additional net budget authority to cover the cost of fully accruing retirement (non-add)	(7,479)	(6,060)	(6,567)	(+507)	(+8.4%)

[a] On December 20, 2002, the National Nuclear Security Administration (NNSA) disestablished the Albuquerque, Oakland, and Nevada Operations Offices, renamed existing area offices as site offices, established a new Nevada Site Office, and established a single NNSA Service Center to be located in Albuquerque. Other aspects of the NNSA organizational changes will be phased in and consolidation of the Service Center in Albuquerque will be completed by September 30, 2004. For budget display purposes, DOE is displaying non-NNSA budgets by site in the traditional pre-NNSA organizational format.

[b] Includes TIM and ERA as proposed by the House EWD Appropriations Subcommittee to be effective in FY 2003.

[c] Excludes $4,460,000 in FY 2002 and $5,460,000 in FY 2003 for Science Education transferred to new Workforce Development for Teachers and Scientists program in FY 2004.

Site Description

Berkeley Site Office

The Berkeley Site Office provides institutional program management oversight in the execution of science programs contracted through Lawrence Berkeley National Laboratory (LBNL). LBNL is a multi-program laboratory located in Berkeley, California on a 200-acre site adjacent to the University of California campus. This activity contributes to ERA's formulation of long-term and strategic plans.

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 administering grants to universities as determined by the DOE sponsoring Program Offices, including non-SC offices, in addition to centrally providing administrative and specialized technical support (i.e., legal advice, personnel management, procurement services, etc.) to the Site Offices responsible for program management oversight for the five major management and operating laboratories--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.

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.

Oak Ridge Operations Office

Oak Ridge supports almost every major Departmental mission in science, energy resources, and environmental quality. They are responsible for grants administration to universities as determined by the sponsoring Program Offices in addition to centralized administrative and specialized technical support (i.e., legal advice, personnel management, procurement services, etc.) to the Oak Ridge National Laboratory and Thomas Jefferson National Accelerator Facility Site Offices.

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.

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 carries out research in the area of retrospective analysis of research outcomes. This activity includes expert assessment of program impacts on other areas of research and the development of research tools.

Office of Scientific and Technical Information

The Office of Scientific and Technical Information (OSTI) is located on a 7-acre site in Oak Ridge, Tennessee. The OSTI facility is a 132,000 square foot secure, fire-protected, humidity-controlled building housing federal and contractor staff and over 1.2 million classified and unclassified documents. The physical facility is approximately 50 years old and is in need of large-scale capital improvements to ensure the safety and health of its occupants and to protect its contents. The large collection represents a critical component of the mission of the TIM subprogram, which is to lead DOE e-government initiatives for disseminating information resulting from the Department's multi-billion annual research and development (R&D) program. This information is the primary deliverable from DOE's $8 billion annual R&D expenditure as reported in technical reports, scientific journal articles, and preprints.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a multi-program 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 ERA formulation of long-term plans and science policy. This activity includes assessments of trends in R&D and the development of science management tools for R&D portfolio and outcome analyses. PNNL also provides expert assistance in state-of-the-art science communications.

Sandia National Laboratories

Sandia National Laboratories (SNL) is a multi-program 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 ERA formulation of best practices for long term plans, science policy and peer reviews. This activity includes assessments of best practices in R&D organizations.

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 laboratory operated under a contract with Stanford University.

Program Direction

Mission Supporting Goals and Measures

The Program Direction subprogram funds all of the SC Federal staff in Headquarters responsible for directing, administering, and supporting the broad spectrum of scientific disciplines. These disciplines include High Energy Physics, Nuclear Physics, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, and Advanced Scientific Computing Research programs. Additionally, this subprogram supports management, human resources, policy, and technical and administrative support staff responsible for 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. By supporting its Federal workforce, SC is able to successfully administer major Federal science programs and projects and facilities across the nation in a safe, secure, and efficient manner.

Accomplishments

- 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.
- Established a Workforce Restructuring Project that will realign the SC Headquarters and Field structure to streamline and improve the management and implementation of programs by reducing layers of management, streamlining decision-making processes, clarifying lines of authority, and utilizing resources more efficiently throughout SC and its Field sites. The changes planned are consistent with both the President's Management Agenda and SC's Business Vision. The Restructuring Project will determine staffing needs throughout the SC complex prior to the end of FY 2004.
- Clarify program, project management, and operational roles and responsibilities to achieve an organization that is stronger in scientific, technical and project management skills, and leaner and more integrated in administrative and support functions.
- Completed the Laboratory Best Practices Study in December 2001. Significant recommendations included simplifying line management accountability, replacing transactional oversight with performance-based management, use of external standards where possible, use of bilateral decision process for directives, and reflecting such changes in contractual language with the laboratories.
- Established a working group, in response to the challenge by the Under Secretary, to develop the principles and guidelines for a new SC contract for the SC multi-program laboratories. The guidelines should lay the groundwork for a streamlined oversight approach that builds trust and accountability, enables the contractors to make sound business decisions, and perform excellent R&D work in the most cost effective and efficient manner, with minimal risk and environmental impact.

Subprogram Goals

Implement comprehensive Human Capital Management initiatives consistent with an SC-wide workforce reengineering, restructuring and succession planning effort. Expand and integrate E:Government/Commerce and Electronic Procurement activities into the SC business systems and processes. Implement a corporate-wide information technology initiative that enables the DOE to effectively manage a broad R&D portfolio.

Performance Indicators

Increased employee/supervisor ratios from FY 2002 levels and elimination of senior level management/organization layer(s). Increased use of electronic technology business applications and the number of research proposals received electronically. Increased receipt and use of electronic information and data on R&D programs and projects by and for multiple users, e.g., DOE program/project managers, national laboratories, universities and private industry.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Initiated program planning on an SC wide workforce restructuring and reengineering effort. Advertised all recruit actions for scientific and technical positions via the automated DOE Jobs Online. Simplified SC position descriptions reducing administrative burden/processing time for position classification. Implemented (1) WorkSheet Exchange system that provides the ability to electronically update the SC corporate financial database with formulation data; (2) an Abstract Tracking system that collects, manages, and publishes abstracts on-line; and (3) 26 enhancements to the Execution Work Management system that supports the grants and Field work proposal process. Identified streamlined processes and high-level requirements for the receipt and management of annual Field budget information for R&D through business process reengineering. Defined requirements to receive new research project information electronically through the DOE integrated electronic procurement system.	Eliminate at least one layer of senior level management and clarify lines of authority, communication and programmatic responsibilities. Implement a system that manages SC's concurrence processes and supports records and document management. Electronically receive (1) 50% of all DOE Field budget information for on-going R&D projects and (2) 80% of all new research project information through the DOE integrated electronic procurement system. Identify streamlined processes and requirements for the tracking and reporting of information for R&D through business process reengineering.	Implement workforce restructuring and reengineering actions and assess the implementation effectiveness. Adjust actions as necessary to ensure organizational and work process changes are in place (e.g., organizational/structural realignment, workforce restructuring). Implement an electronic business management database and tracking application that supports the SC leadership in establishing scientific research priorities. Electronically receive (1) 80% of all DOE Field budget information for on-going R&D projects and (2) 100% of all new research project information through the DOE integrated electronic procurement system. Develop and test an electronic R&D project management and tracking database application for the DOE program managers that incorporates information from other DOE corporate systems.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Headquarters					
Salaries and Benefits	32,769	33,851	36,077	+2,226	+6.6%
Travel	1,506	1,564	1,564	0	--
Support Services	10,041	10,882	11,850	+968	+8.9%
Other Related Expenses	7,029	9,687	8,726	-961	-9.9%
Total, Headquarters	51,345	55,984	58,217	+2,233	+4.0%
Additional net budget authority to cover the cost of fully accruing retirement (non-add)	(2,070)	(2,240)	(1,923)	(-317)	(-14.2%)
Full Time Equivalents	261 [a]	284 [a]	284	0	--

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Salaries and Benefits	**32,769**	**33,851**	**36,077**

This funds 284 FTEs in Headquarters during our Workforce Restructuring Project which will be completed by the end of FY 2004. The FY 2004 FTE request is consistent with the FY 2002 authorized level.

	FY 2002	FY 2003	FY 2004
Travel	**1,506**	**1,564**	**1,564**

Travel includes all costs of transportation of persons, subsistence of travelers, and incidental travel expenses in accordance with Federal travel regulations.

	FY 2002	FY 2003	FY 2004
Support Services	**10,041**	**10,882**	**11,850**

Provides funding for general administrative services and technical expertise provided as part of day-to-day operations, including mailroom operations; travel management; environment, safety and health (ES&H) support; security and cyber security support; and administering the Small Business Innovation Research (SBIR) program. Also provides for information technology (IT) maintenance and enhancements, including support for the e-R&D Portfolio Management, Tracking and Reporting Project.

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[a] Revised estimate based on reprioritization of FY 2002 and FY 2003 activity to avoid IRIFs in both fiscal years. The FY 2002 Comparable Appropriation in the FY 2003 President's Request was 293. The FY 2003 President's Request was 299 FTEs.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

The $968,000 increase allows SC to fund additional costs (+$550,000) for administrative and technical support service contracts due to increased work requirements, such as implementation of more stringent foreign travel procedures mandated since the September 11 terrorist attacks. Funding (+$506,000) enables SC to develop and implement integrated business applications consistent with the President's e-government initiatives. SC promotes IT efficiencies consistent with the provisions of the Information Technology Management Reform Act of 1996 to improve how the mission is accomplished. In FY 2004, technical assistance is reduced (-$88,000) in order to support other critical needs within the Office of Science Program Direction budget. At this level of funding the e-R&D Portfolio Management, Tracking and Reporting Project will develop and implement a system to allow for the electronic receipt of DOE laboratory proposals. Additional functionality will be delivered in future years to provide project query and reporting capabilities, and further testing and integration with other corporate IT initiatives.

Other Related Expenses	**7,029**	**9,687**	**8,726**

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, e-R&D Portfolio Management, Tracking and Reporting Project acquisitions, etc. The $961,000 decrease is the result of several items: a reduction in hardware/software goods and services in support of the e-R&D Portfolio Management, Tracking and Reporting Project requirements (-$1,470,000); the completion of the Workforce Restructuring Project by September 30, 2003, designed to identify ways to a) reduce the number of managers, organizational layers, and time needed to make decisions; b) increase the span of control; and c) redirect positions to the front lines (+478,000); supports anticipated IT efficiencies (-$107,000); and growth in the WCF (+$138,000).

Total, Program Direction	**51,345**	**55,984**	**58,217**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Salaries and Benefits	
■ Supports 284 FTEs and factors 2.4 percent pay adjustment in personnel compensation.	+2,226
Support Services	
■ Dedicates funding to development of integrated business applications	+506
■ Decrease in technical support for the e-R&D Portfolio Management, Tracking and Reporting Project	-88

	FY 2004 vs. FY 2003 ($000)
■ Funds increased support service contract activity requirements in the areas of ES&H; safeguards and security; mail room and travel management; and SBIR (+$550,000)	+550
Total, Support Services	+968
Other Related Expenses	
■ Decrease in e-R&D Portfolio Management, Tracking and Reporting Project architecture acquisitions	-1,470
■ Reflects continuing efforts towards completion of the Workforce Restructuring Project by December 31, 2004, consistent with the President's Management Agenda Initiatives	+478
■ Supports SC Headquarters IT requirements	-107
■ Fund activities provided in the WCF	+138
Total, Other Related Expenses	-961
Total Funding Change, Program Direction	+2,233

Support Services

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Technical Support Services					
Test and Evaluation Studies	650	700	750	+50	+7.1%
Total, Technical Support Services	650	700	750	+50	+7.1%
Management Support Services					
ADP Support	8,170	8,982	9,400	+418	+4.7%
Administrative Support	1,221	1,200	1,700	+500	+41.7%
Total, Management Support Services	9,391	10,182	11,100	+918	+9.0%
Total, Support Services	10,041	10,882	11,850	+968	+8.9%

Other Related Expenses

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Training	96	99	99	0	--
Working Capital Fund	4,150	4,200	4,338	+138	+3.3%
Information Technology Hardware and Software/Maintenance Acquisitions	640	3,071	1,494	-1,577	-51.4%
Other	2,143	2,317	2,795	+478	+20.6%
Total, Other Related Expenses	7,029	9,687	8,726	-961	-9.9%

Field Operations

Mission Supporting Goals and Measures

The Field Operations subprogram is the centralized funding source for the SC Field Federal workforce responsible for the management and administrative functions at the Chicago and Oak Ridge Operations Offices and the Site Offices supporting SC laboratories and facilities, e.g., Ames Site Office; Argonne Site Office; Brookhaven Site Office; Fermi Site Office; Lawrence Berkeley National Laboratory Site Office; Oak Ridge National Laboratory Site Office; Princeton Plasma Physics Laboratory Site Office; Thomas Jefferson National Accelerator Facility Site Office; and Stanford Linear Accelerator Center Site Office.

This subprogram supports the Federal workforce that is responsible for SC and other DOE programmatic missions performed in support of science and technology, energy research, and environmental management, i.e., 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, and information systems development and support.

In addition, this subprogram provides funding for the fixed requirements associated with rent, utilities, and telecommunications. Other requirements such as IT 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. This subprogram also supports the Inspector General operations located at each site by providing office space and materials. 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.

Accomplishments

- 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.
- 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 feature of the Corporate Human Resources Information System. Federal employees can now view payroll, benefits, and other personal information at their desktops via Internet access.

Subprogram Goals

Implement comprehensive Human Capital Management initiatives consistent with an SC-wide workforce reengineering, restructuring and succession planning effort. Expand and integrate e-Government/Commerce and Electronic Procurement activities into the SC business systems and processes. Implement a corporate-wide information technology initiative that enables the DOE to effectively manage a broad R&D portfolio.

Performance Indicators

Increased employee/supervisor ratios from FY 2002 levels and elimination of senior level management/organization layer(s). Increased use of electronic technology business applications and the number of research proposals received electronically. Increased receipt and use of electronic information and data on R&D programs and projects by and for multiple users, e.g., DOE program/project managers, national laboratories, universities and private industry.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Initiated program planning on an SC wide workforce restructuring and reengineering effort. Advertised all recruit actions for scientific and technical positions via the automated DOE Jobs Online. Simplified SC position descriptions reducing administrative burden/processing time for position classification. Implemented (1) WorkSheet Exchange system that provides the ability to electronically update the SC corporate financial database with formulation data; (2) an Abstract Tracking system that collects, manages, and publishes abstracts on-line; and (3) 26 enhancements to the Execution Work Management system that supports the grants and Field work proposal process. Identified streamlined processes and high-level requirements for the receipt and management of annual Field budget information for R&D through business process reengineering. Defined requirements to receive new research project information electronically through the DOE integrated electronic procurement system.	Eliminate at least one layer of senior level management and clarify lines of authority, communication and programmatic responsibilities. Implement a system that manages SC's concurrence processes and supports records and document management. Electronically receive (1) 50% of all DOE Field budget information for on-going R&D projects and (2) 80% of all new research project information through the DOE integrated electronic procurement system. Identify streamlined processes and requirements for the tracking and reporting of information for R&D through business process reengineering.	Implement workforce restructuring and reengineering actions and assess the implementation effectiveness. Adjust actions as necessary to ensure organizational and work process changes are in place (e.g., organizational/structural realignment, workforce restructuring). Implement an electronic business management database and tracking application that supports the SC leadership in establishing scientific research priorities. Electronically receive (1) 80% of all DOE Field budget information for on-going R&D projects and (2) 100% of all new research project information through the DOE integrated electronic procurement system. Develop and test an electronic R&D project management and tracking database application for the DOE program managers that incorporates information from other DOE corporate systems.

Funding Schedule

	(dollars in thousands, whole FTEs)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	26,106	24,421	27,355	+2,934	+12.0%
Travel	403	340	494	+154	+45.3%
Support Services	6,670	1,666	2,307	+641	+38.5%
Other Related Expenses	2,656	1,298	3,590	+2,292	+176.6%
Total, Chicago Operations Office	35,835	27,725	33,746	+6,021	+21.7%
Full Time Equivalents	252	267	267	0	--
Berkeley/Stanford Site Offices					
Salaries and Benefits	2,370	2,392	2,463	+71	+3.0%
Travel	60	48	48	0	--
Support Services	270	0	0	0	--
Other Related Expenses	300	421	320	-101	-24.0%
Total, Berkeley/Stanford Site Offices	3,000	2,861	2,831	-30	-1.0%
Full Time Equivalents	23	25	25	0	--
Oak Ridge Operations Office					
Salaries and Benefits	28,844	29,046	29,852	+806	+2.8%
Travel	479	387	395	+8	+2.1%
Support Services	12,116	8,174	11,868	+3,694	+45.2%
Other Related Expenses	9,317	4,210	5,110	+900	+21.4%
Total, Oak Ridge Operations Office	50,756	41,817	47,225	+5,408	+12.9%
Full Time Equivalents	316	317	317	0	--
Total Field Operations					
Salaries and Benefits	57,320	55,859	59,670	+3,811	+6.8%
Travel	942	775	937	+162	+20.9%
Support Services	19,056	9,840	14,175	+4,335	+44.1%
Other Related Expenses	12,273	5,929	9,020	+3,091	+52.1%
Total, Field Operations	89,591	72,403	83,802	+11,399	+15.7%
Additional net budget authority to cover the cost of fully accruing retirement (non-add)	(4,928)	(3,392)	(4,065)	(+673)	(+19.8%)
Full Time Equivalents	591 [a]	609 [a]	609	0	--

[a] Revised estimate based on reprioritization of FY 2002 and FY 2003 activity to avoid IRIFs in both fiscal years. The FY 2002 Comparable Appropriation in the FY 2003 President's Request was 676 FTEs. The FY 2003 President's Request was 467 FTEs.

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Salaries and Benefits..	**57,320**	**55,859**	**59,670**

Supports 609 FTEs within the SC Field complex, 18 FTEs more than FY 2002 (591 FTEs). Past unstructured downsizing across SC has resulted in under-staffing in some areas and over-staffing in others. To address this, SC is working on a phased approach that spans multiple years. SC has initiated a Workforce Restructuring Project that will establish a direct reporting relationship between SC site offices and SC Headquarters, thus removing a layer of management currently residing in the Chicago and Oak Ridge Operations Offices. These operations offices will be transformed into one or more service centers, with redefined roles and responsibilities to provide best-in-class business, administrative, and specialized technical support across the entire SC enterprise and, as appropriate, to other DOE programs.

Travel	**942**	**775**	**937**

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..	**19,056**	**9,840**	**14,175**

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 IT routine computer maintenance, specific improvements, operating systems upgrades, cyber security, network monitoring, firewalls, and disaster recovery tools. Other areas include staffing 24-hour emergency and communications centers, safeguarding and securing assets (protective guards, processing security clearances, classifying records, protecting assets and property, etc.), processing/distributing mail, travel management centers, contract close-out activities, copy centers, directives coordination, filing and retrieving records, etc. Requirements in FY 2003 appear artificially low because some of the requirements will be funded in FY 2003 from FY 2002 uncosted balances to avoid IRIFs in FY 2003. The funding increase from FY 2003 to FY 2004 reflects the level to which day-to-day operations are being restored in order to maintain a viable work environment.

Other Related Expenses	**12,273**	**5,929**	**9,020**

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, office equipment/furniture, building maintenance, etc. Employee training and development and the supplies and furnishings used by the Federal staff are also included. Requirements in FY 2003 appear artificially low because some of the requirements will be funded in FY 2003 from FY 2002 uncosted balances to avoid IRIFs in FY 2003. The funding increase from FY 2003 to FY 2004 reflects the level to which day-to-day operations are being restored in order to sustain a productive work environment.

Total, Field Operations	**89,591**	**72,403**	**83,802**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Salaries and Benefits	
■ Supports 609 FTEs within the SC Field complex, 18 FTEs more than FY 2002 (591 FTEs). Also factors a 2.4 percent pay adjustment in personnel compensation ...	+3,811
Travel	
■ Commensurate support for Federal FTEs	+162
Support Services	
■ Restore funding for support service activities (contract closeout, mail/travel management, safeguards and security functions, etc.) funded in FY 2003 from FY 2002 uncosted balances to avoid IRIFs in FY 2003.	+4,335
Other Related Expenses	
■ Restore funding in support of day-to-day activities such as building services and maintenance, janitorial, other supplies and materials, and systems support; i.e., the Financial Service Center processes. These activities will be funded in FY 2003 from FY 2002 uncosted balances to avoid IRIFs in FY 2003......................................	+3,091
Total Funding Change, Field Operations	+11,399

Support Services

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Technical Support Services					
Economic and Environmental Analysis	5,612	0	0	0	--
Total, Technical Support Services	5,612	0	0	0	--
Management Support Services					
ADP Support	6,529	4,064	4,064	0	--
Administrative Support	6,915	5,776	10,111	+4,335	+75.1%
Total, Management Support Services	13,444	9,840	14,175	+4,335	+44.1%
Total, Support Services	19,056	9,840	14,175	+4,335	+44.1%

Other Related Expenses

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Training	600	65	65	0	--
Printing and Reproduction	380	250	250	0	--
Rent & Utilities & Telecommunication	6,536	3,495	3,395	-100	-2.9%
Information Technology Hardware, Software, and Maintenance	1,467	1,000	1,000	0	--
Working Capital Fund	474	500	500	0	--
Other	2,816	619	3,810	+3,191	+515.5%
Total, Other Related Expenses	12,273	5,929	9,020	+3,091	+52.1%

Technical Information Management

Mission Supporting Goals and Measures

R&D is the process of exploration, discovery, and sharing of the knowledge gained. Scientific progress is only possible if knowledge is shared. The Technical Information Management (TIM) subprogram is instrumental in directly performing this critical part of the R&D cycle. TIM collects the research results, maintains the information, and makes that information available to the broader scientific community to contribute to the advancement of science, thereby completing the cycle of building on knowledge previously gained and combining it with newly discovered insights. TIM assures that the scientific and technical information emanating from the myriad DOE research activities is effectively managed and disseminated per legislative mandates to benefit the nation.

DOE's missions in science and technology, national defense, energy resources, and environmental stewardship are all dependent on a strong base of R&D. DOE R&D activities are decentralized, occurring at national laboratories, in academia, and among individual contractors. TIM organizes these widely-dispersed research results into searchable sets. Using innovative information technologies, TIM makes them available to the widest possible audience in accordance with the body of legislation that dictates DOE's responsibilities to share information. In this manner, DOE is assured of having historic and current research results readily available and reusable to advance its missions; providing access to those in R&D pursuits and to the science-attentive public; and promoting and safeguarding national security interests. TIM projects and initiatives deliver the scientific knowledge emanating from DOE via cost-effective e-government information retrieval systems. These initiatives help make science information more visible and useable.

TIM Program Direction funding provides staffing and resources to both direct and execute the TIM subprogram mission. Federally-staffed functions include policy development and integration; U.S. and DOE representation in interagency and international information exchange agreements; management of safeguards and security activities; administration; personnel management; budget formulation and execution; procurement and contract management; records management; classified information program management; facility management; and collecting, preserving, organizing, and disseminating the information resulting from DOE's R&D investment, including re-engineering mission-critical systems to take full advantage of electronic information technology. As a result of the capabilities TIM uses to fulfill Department-wide responsibilities, it also provides, on a cost-reimbursable basis, specialized scientific and technical information systems or services to individual DOE Program Offices.

Accomplishments

- Progress with Information Technology and e-Government Practices: The TIM subprogram is instrumental in performing the sharing of knowledge – a critical part of the R&D cycle. Broad access, preservation, and electronic availability of this knowledge are critical. By implementing innovative information technologies, TIM has drastically changed the manner by which it does business, moving from a paper-based to an electronic work environment. As measured by the quantity of STI disseminated and the number of patrons served, TIM plays a more useful role now than in prior years. For example, in the paper environment (1995), TIM distributed 10,000 reports per year upon request; now, patrons of TIM's web-based systems are downloading 260,000 full-text reports (plus a much larger number of individual page views) per year. In 2001, TIM's web sites and e-government information systems logged nearly 6,000,000 user transactions – a 79 percent increase over the previous year. In addition, using electronic delivery of information has resulted in a 90 percent reduction in the cost per user transaction.

- Shift in Coverage of Journal Literature: Unveiled in 1999, PubSCIENCE provided researchers and science-attentive citizens access via the web to bibliographic records of peer-reviewed journal literature relating to DOE-supported work. PubSCIENCE was a modern tool to fulfill a longstanding responsibility to provide access to a collection of R&D records created by or relevant to DOE researchers. PubSCIENCE effectively served its purpose, offering citations in disciplines of interest to DOE at a time when no equivalent free-for-use private sector service was available. However, in FY 2002, after analyzing the availability of freely searchable journal citations now available via the web through secondary information providers Scirus and Infotrieve, TIM concluded that these private sector products fulfilled the needs in coverage at no cost to users. Consequently, the Department proposed to cease operation of PubSCIENCE and conducted a 30-day public notice period, as required by law; PubSCIENCE was terminated on November 4, 2002. TIM is now focused on improving coverage of DOE-sponsored journal literature, consistent with findings of several recent Inspector General reports. Information technology and software have matured, allowing for a more focused and simplified mechanism to access and account for DOE R&D results. DOE is making arrangements within the DOE community to compile this information. The modest resources that previously supported PubSCIENCE have been redirected to deploy new technologies specifically to harvest DOE journal information directly from the DOE Laboratories, contractors, and grantees.
- Board of Visitors Program Review: In June 2002, a distinguished Board of Visitors was unified in their support of TIM and the critical nature of its mission. The members of the Board specifically cited TIM's significant progress in rapidly shifting from a paper-based operation to an efficient web-based environment; partnering and collaborating with other federal agencies and the private sector in promoting e-government systems; and maintaining a professional, productive workforce amidst severe resource constraints.
- *Science.gov* Alliance: The TIM subprogram continues its participation in the development and enhancement of *science.gov*, the Interagency Science web resource. Hosted by OSTI, *science.gov* has 12 participating federal agencies bringing S&T to citizens, including scientists, teachers, students, and business people via one Internet site. *Science.gov* provides an integrated place to search and access previously hard-to-find government sponsored R&D projects and results, through a single query. Different options and paths are available for a diverse body of users. *Science.gov* provides a giant leap toward making e-government a reality and the U.S. an international leader in the area of STI exchange.
- Awards and Recognition: The TIM subprogram has demonstrated "first in class" capabilities in information collection, processing, and dissemination technologies and concepts, resulting in recognition and increased visibility for the Department and the SC. Specific recognition from outside the Department includes a commendation from the Depository Library Council of the GPO for TIM's Energy Citations Database (January 2002), and the 2001 Interagency Resource Management Conference (IRMCO) Award for demonstrating exceptional ability to operate across organizational boundaries to improve the government's service to its people (September 2001). Further, TIM was invited to write an article summarizing TIM's information technology advances for "Nature" magazine (May 2001). Within the Department, support and acknowledgement for TIM's successes is indicated by the 2001 DOE IT Quality Award for Management/Administrative Excellence recognizing TIM's leadership in implementing a streamlined system for providing legacy and current DOE STI in the Energy Citations Database (March 2002); DOE Secretarial Certificate of Achievement recognizing TIM and Scientific and Technical Information Program partners at DOE

field offices and laboratories for the completion of a successful transition from paper to electronic technical information reporting in support of DOE's R&D mission, three years ahead of the DOE goal (March 2002); and 2000 DOE-Wide IT Quality Award for capitalizing on technological advances in the Information Age to bring science information to the desktops of U.S. and DOE researchers (March 2001).

Subprogram Goals

Deliver the scientific knowledge generated by or relevant to DOE's R&D program via cost-effective e-government information retrieval systems to government, university, and industry users "so as to provide free interchange of ideas and criticism which is essential to scientific and industrial progress and public understanding and to enlarge the fund of technical information" (excerpt from 42 U.S.C. § 2161). Provide stewardship for the Department's legacy of classified and unclassified STI; contribute to the Nation's overall information infrastructure through partnerships with international organizations and other government information dissemination organizations such as the International Energy Agency's Energy Technology Data Exchange (ETDE), International Atomic Energy Agency's International Nuclear Information System (INIS), *science.gov* Alliance, Government Printing Office (GPO), National Technical Information Service, and CENDI (Commerce, Energy, Education, EPA, NASA, NLM, Defense, and Interior) organizations.

Performance Indicators

Increased amount of DOE-sponsored STI available online and increased use of STI. Increased amount of international STI available electronically.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Advanced science knowledge and its application by providing access to 5,000 new full-text technical reports and increased access to preprint servers from 5,200 to 8,000 sites.	Increase the number of new full-text technical reports available online by 5,000.	Increase the number of new full-text scientific and technical (S&T) documents available electronically by 5,000 to a total of 75,000 and maintain access to over 2,000,000 citations. Increase in use of STI by 10 percent from a projected FY 2002 baseline of 6,000,000.
Represented DOE in the *science.gov* Alliance by providing a web-based search tool for over 30 multi-agency databases.	Continue to support the *science.gov* Alliance and establish the content and user base in partnership with other government agencies.	Continue to support the *science.gov* Alliance by hosting the *science.gov* website.
Through international partnerships, made 80,000 new international research records available through web-based databases.	Increase the volume of international full-text information made electronically available to U.S. citizens by 5 percent.	Increase the volume of international full-text information made electronically available to U.S. citizens by 5 percent.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
TIM Program Support					
E-Government Information Systems	696	898	750	-148	-16.5%
R&D Tracking System	202	202	200	-2	-1.0%
Foreign R&D Records	100	100	100	0	--
Electronic and Paper Document Storage	200	200	200	0	--
Subtotal, TIM Program Support	1,198	1,400	1,250	-150	-10.7%
TIM Program Direction					
Oak Ridge, TN					
Salaries and Benefits	5,860	6,011	6,006	-5	-0.1%
Travel	75	80	80	0	--
Support Services	100	100	100	0	--
Other Related Expenses	200	200	200	0	--
Total, Oak Ridge, TN	6,235	6,391	6,386	-5	-0.1%
Full Time Equivalents	74	71	71	0	--
Headquarters					
Salaries and Benefits	130	134	138	+4	+3.0%
Travel	0	0	0	0	--
Support Services	0	0	0	0	--
Other Related Expenses	0	0	0	0	--
Total, Headquarters	130	134	138	+4	+3.0%
Full Time Equivalents	1	1	1	0	--
Subtotal TIM Program Direction					
Salaries and Benefits	5,990	6,145	6,144	-1	--
Travel	75	80	80	0	--
Support Services	100	100	100	0	--
Other Related Expenses	200	200	200	0	--
Subtotal, TIM Program Direction	6,365	6,525	6,524	-1	--
Additional net budget authority to cover the cost of fully accruing retirement (non-add)	(481)	(428)	(579)	(+151)	(+35.3%)
Full Time Equivalents	75	72	72	0	--
Total, Technical Information Management	7,563	7,925	7,774	-151	-1.9%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
E-Government Information Systems	**696**	**898**	**750**

The TIM subprogram continues to lead DOE e-government initiatives for disseminating information, which include building the world's most comprehensive collection of physical sciences information and providing greater free, electronic, public access to full-text gray literature, journal literature, and preprints. Activities supported include the following:

- DOE Information Bridge. The free, publicly accessible DOE Information Bridge, which contains searchable, full-text access to over 70,000 technical reports (over 5 million pages) from DOE research projects, enables users to bypass expensive and time-consuming bibliographic searches and requests for paper reports. As technology and common standards advance, it becomes more timely and economical to exchange information in electronic media. Hailed as a "model" for other interagency collaborations by the Chairman of the Joint Committee on Printing, the public version of the DOE Information Bridge is available through a partnership with the GPO.
- PrePRINT Network. The PrePRINT Network is a searchable gateway to preprint servers that deal with scientific and technical disciplines of concern to DOE and provides access to over 8,000 preprint sites worldwide with over 500,000 preprints in full text. Such disciplines include the great bulk of physics, materials, and chemistry, as well as portions of biology, environmental sciences, and nuclear medicine. The PrePRINT Network also features an alert service that enables researchers to set up a personalized profile and receive notification of new additions in their areas of interest.
- Energy Citations Database. The Energy Citations Database contains over 2,000,000 bibliographic citations for energy and energy-related STI from the DOE and its predecessor agencies. Through this database, TIM provides free access to DOE publicly-available citations from 1948 through the present and includes citations to report literature, conference papers, journal articles, books, dissertations, and patents in disciplines of interest to DOE.
- DOE R&D Accomplishments. DOE R&D Accomplishments is a central forum for information about the outcomes of past DOE R&D which has had significant economic impact, has improved people's lives, or has been widely recognized as a remarkable advancement in science. The site contains searchable full-text and bibliographic citations of documents reporting accomplishments from DOE and DOE contractor facilities.
- EnergyFiles. EnergyFiles is the virtual library of energy science and technology, and is a comprehensive resource of on-line information systems, including those developed by the TIM subprogram and other government organizations. EnergyFiles provides both researchers and the general public with ever-expanding desktop access to over 500 STI resources, searchable by 14 subject categories**.** Users can search full-text heterogeneous information sources with a distributed, single query search tool called Energy Portal.
- Capital Equipment. Capital equipment funding is included for computer hardware (Sun fire server with SPARC technology) to support electronic information exchange efforts of ORACLE database.

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		
R&D Tracking System	**202**	**202**	**200**

The DOE R&D Tracking System is the Department's centrally-managed database that tracks key information about each R&D project sponsored or performed by DOE. The System is used for a variety of needs including responding to the annual OSTP data call, facilitating the Department's tracking of R&D projects, and reducing the time spent in responding to ad hoc data calls from within and outside the Department. The R&D Tracking System provides an on-line mechanism for Program Offices and the DOE laboratories to review, manage, update, and analyze the Department's multi-billion dollar R&D program. The R&D Project Summaries Database, the web- based public version of the DOE R&D Tracking System, provides open access to DOE R&D project summaries to U.S. industry, educators, and the public.

Foreign R&D Records	**100**	**100**	**100**

Other industrialized nations are also investing in energy R&D, and the resulting technical information is globally recognized as a valuable commodity that can be exchanged in order to save taxpayer dollars and avoid duplicative research. As an international leader in the area of STI exchange, the TIM subprogram represents DOE and the U.S. in two international information exchanges, the International ETDE and the INIS. Through these exchanges, TIM acquires access to foreign research results. The ETDE agreement involves the exchange of energy-related information among 18 industrialized nations. INIS involves the exchange of nuclear energy information among over 104 countries and 19 international organizations. Funding at the requested level enables the Department to acquire approximately 80,000 new international research records on behalf of the domestic science community through the ETDE partnership.

Electronic and Paper Document Storage	**200**	**200**	**200**

The TIM subprogram's physical facility is the one place where the Department's collection of STI can be found. With the transition to the electronic information age, the repository function for the nation's energy-related science base must adapt to the new media. Interagency standards and agreements must be developed, adopted, and implemented while conserving resources and promoting information access and retrievability. The requested funding level allows for continued storage and preservation of a 50-year archive of 1.2 million historical technical reports. The TIM subprogram also maintains a classified information program that collects, preserves, and exchanges classified, sensitive, and limited circulation documents and houses a comprehensive repository of energy- and weapons-related classified information in a secure environment.

Subtotal, TIM Program Support	**1,198**	**1,400**	**1,250**

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
TIM Program Direction			
Salaries and Benefits	**5,990**	**6,145**	**6,144**

In the TIM subprogram, Federally-staffed functions include policy development and integration; U.S. and DOE representation in interagency and international information exchange agreements; management of safeguards and security activities; administration; personnel management; budget formulation and execution; procurement and contract management; records management; classified information program management; facility management; and collecting, organizing, preserving, and disseminating information resulting from DOE's R&D investment, including re-engineering mission-critical systems to take advantage of electronic information technology. Federal staff implements programs and practices involving all national laboratories and over 7,000 other DOE research entities producing STI.

Travel	**75**	**80**	**80**

Travel funding supports a nationwide program involving national laboratories and thousands of research entities, including coordination of common exchange standards. Alternatives to travel such as teleconferencing will continue to be utilized when possible.

Support Services	**100**	**100**	**100**

Provides for testing systems and concepts related to the TIM subprogram, web-based tools and services, and internal and external automatic data processing as well as support services needed for mailroom operations, environment, safety and health support, computer systems development, and hardware and software installation, configuration, and maintenance activities. Also includes support services needed for safeguards and security activities.

Other Related Expenses	**200**	**200**	**200**

Expenses reflect facility maintenance costs, training for federal employees, telecommunications enhancements designed to support information dissemination, and acquisition of computer hardware and software necessary to accomplish network upgrades.

Subtotal, TIM Program Direction	**6,365**	**6,525**	**6,524**
Total, Technical Information Management	**7,563**	**7,925**	**7,774**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Program Support	
The decrease is a result of the savings achieved by reducing resources dedicated to the development of new e-government information systems. In FY 2004, resources will be dedicated to maintenance of existing systems	-150
Total Funding Change, TIM Program Support	-150
Program Direction	
■ Support for Program Direction is continued at the FY 2003 level.	-1
Total Funding Change, TIM Program Direction	-1
Total Funding Change, TIM	-151

Support Services

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Technical Support Services					
Test and Evaluation Studies	70	70	70	0	--
Total, Technical Support Services	70	70	70	0	--
Management Support Services					
ADP Support	30	30	30	0	--
Total, Management Support Services	30	30	30	0	--
Total, Support Services	100	100	100	0	--

Other Related Expenses

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Training	10	10	10	0	--
Rental Spaces/Utilities	180	180	180	0	--
Software Procurement/Maintenance Activities/Capital Acquisitions	10	10	10	0	--
Total, Other Related Expenses	200	200	200	0	--

Energy Research Analyses

Mission Supporting Goals and Measures

The Energy Research Analyses (ERA) subprogram supports SC programs through the development of management tools and support, analysis of policy direction set by the Administration and the Congress, development and integration of SC strategic plans and research portfolios, evaluation of programs and performance, and facilitation of SC collaborations with other Federal agencies and major stakeholders.

Accomplishments

- The SC responsiveness to Government Performance and Results Act (GPRA) requirements was improved in FY 2002 through an evaluation of performance measures by a panel of experts under the Basic Energy Sciences Advisory Committee, the development of new tools and analysis mechanisms, and innovative research that has a goal of improving the performance metrics that a basic research organization should use to comply with GPRA.
- Strategic planning efforts were informed by the results of ongoing research and from a 3-year science foresighting study.
- Science policy studies and scientific research trend analyses were provided to SC program managers and to other public science organizations in FY 2002, including the results of case studies in: patent to paper citation analysis; preliminary results in novel performance measures for basic research; and "A Characterization of the Impact of the National Synchrotron Light Source on Life Sciences Research." These studies assess program outcomes and inform future planning efforts. New case studies to document, retrospectively, the outcomes of several elements of the SC Research portfolio were initiated as part of the SC's response to the OMB R&D Investment Criteria including: the "Impacts of the Microbial Genome Program," "Unexpected Applications of a Nuclear Physics Research Tool (Hyperpolarized Gas) Highlighting Fundamental Differences Between The Research Approach Of Mission Agencies When Compared To The National Institutes Of Health;" and "A Research Management Case Study – Applied Math."
- The SC led Federal government efforts to fully implement OMB's R&D Investment Criteria, including sponsoring a major inter-agency workshop that featured expert private sector evaluators.
- A new tool was developed for the analysis of public benefit outcomes from the SC research portfolio. This tool can be used to analyze and characterize the impact of SC research on U.S. patents. One insight the tool revealed provides clear evidence that U.S. companies overwhelmingly garner the most benefit (82%), compared to international companies, from SC and national laboratory research. This tool has been shared with the national laboratories for further development and use in the management of intellectual property.
- Management practices were better informed through the dissemination to DOE senior program managers of the results of a literature review of best practices in science management.
- Science communications was advanced through sponsorship of the first ever government-wide science communications best practice workshop and the complete revamping of the SC website to make it more interactive, informative and useful to the general public.

Subprogram Goals

Develop and implement best-in-class tools and methods for evaluating the excellence, relevance and performance of SC basic research programs; and conduct case studies and other evaluations to document the societal outcomes of SC basic research programs. Conduct prospective analyses of emerging science management issues, future research opportunities, and research portfolio balance to support long-range planning and decision making for SC; and prepare strategic plans for future SC investments built upon its mission, its core competencies, and emerging research issues. Develop tools and methods, communities of practice, effective networks, and deployment strategies to improve access to SC information, programs and resources.

Performance Indicators

Number and quality of evaluation techniques adopted by SC. Number and quality of analyses performed. Indicators of access and awareness of SC program information and resources by different audiences.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
In close collaboration with OMB, Office of Science and Technology Policy (OSTP) and other federal science agencies, develop an implementation strategy for the SC to fully incorporate the OMB R&D Investment Criteria for Basic Research.	Collaborate with OMB, OSTP and other federal science agencies to develop tools and methods for documenting the implementation of the OMB R&D Investment Criteria for Basic Research in the SC.	Develop software tools to manage and gather information about S&T research. This will emphasize investigation within a research area and across research areas to identify unexpected interconnections and impacts.
Initiated four pilot studies – 3 retrospective case studies and 1 prospective study to examine the societal impact of SC research.	Initiate four studies – 3 retrospective case studies and 1 prospective study to examine the societal impact of SC research.	Conduct 3 retrospective case studies to examine the outcomes and societal impact of SC research.
Complete Phase 2 and begin Phase 3 of studies to explore the global challenges over next 25 years that may affect future S&T management and policy.	Complete Phase 3 and prepare final set of scenarios on S&T management challenges that may emerge over the next 25 years.	The results of the studies commissioned in FY 2002 and FY 2003 will inform the work being pursued in FY 2004.
Create unique tools to identify the impact of publicly funded science on our nation's economy and scientific enterprise.	Conduct a study on the linkages between seemingly disparate branches of science with regard to reliance on large-scale research tools.	Advance the use of datamining and visualization tools for R&D portfolio.
Benchmark the U.S. position in international science.	Create unique resources using datamining and visualization tools for R&D portfolio management.	
Improve and integrate performance planning and measures between budget documents and DOE performance plans.	Publish results of quantitative performance measures study in open literature; fully incorporate into SC evaluation regime.	Integrate the retrospective case study findings to develop good metrics to produce excellent management techniques and processes.
Develop guidelines for consistently measuring performance of SC programs. Seek SC advisory committee advice.	Implement advisory committee recommendations. Update and publish the SC strategic plan.	

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Develop overarching strategic framework and strategic themes for new SC strategic plan.		
Sponsored a ground-breaking, international conference on "Best Practices in Public Communication of Science, Health and Technology" including presentation and publication of peer-reviewed papers to widely disseminate best practices.	Implement results of best practices studies. Develop tools to publicize SC's unique scientific achievements, initiate interagency collaborations on implementation and further best-practices research. Develop a standard set of information about each program's benefits and societal impact.	Prior-year study to culminate in integrated approach for validating to a broad audience our scientific achievements, demonstrating the linkages of SC scientific achievements and how it serves as the corner stone to other science agencies.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Energy Research Analyses	968	993	1,020	+27	+2.7%
SBIR/STTR	0	27	0	-27	-100.0%
Total, Energy Research Analyses.......	968	1,020	1,020	0	--

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Energy Research Analyses	**968**	**993**	**1,020**

In FY 2004, ERA will focus on three major areas:

- *Corporate Communications* will communicate the benefit of SC's scientific achievements and ensure that SC contributions and capabilities are widely recognized. The impact and role of the SC in the science and technology infrastructure are not well understood. Communications in this area need improvement. To better understand the barriers to communications, ERA hosted an international conference on "Best Practices in Public Communication of Science, Health and Technology." Lessons learned from this conference are currently being implemented through such efforts as: redesign of the SC web page and improvements to the web-based newsletter "Energy Science News"; improved coordination between the SC and its laboratories through clearer reporting mechanisms and the identification of a single point of contact for each laboratory and for the Office of Science; initiation of a "Science Speakers Bureau"; publication of outcome and public benefit studies in peer-reviewed literature; publication and wide-dissemination of management best practices, including science communications best practices; and stronger interagency collaborations. FY 2004 funding will allow for: continued research on science communications; better training of the Public Affairs practitioners at the National Labs, further improvements to the SC webpage; an increase in the number and quality of SC publications aimed at communicating with the public; increased presence at trade conferences and meetings; and increased use of electronic news media to reach science attentive audiences. ERA also supports management of the Enrico Fermi Awards and the E.O. Lawrence Awards.
- *Case Studies* will be conducted by independent researchers to identify trends in the DOE research portfolio, as well as areas of portfolio performance that could be optimized, and to document the impacts of the basic research supported by the SC. This activity strongly supports SC implementation of the OMB R&D Investment Criteria and the GPRA. FY 2004 funding will allow ERA to characterize and document: the linkages between basic and applied research in the DOE; societal impacts (e.g., improved health, economic growth, etc.) from SC research; the methods by which SC research diffuses through the national S&T infrastructure; and other high impact areas of study that demonstrate the impact of the SC portfolio. All case studies will be submitted for publication in peer-reviewed literature and on the SC webpage. Case studies that identify trends in the DOE research portfolio, such as undesirable duplications and gaps, are part of the legislative mandate of this program and also provide validation of the continued relevance of the SC portfolio to DOE missions as called for in the Investment Criteria.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

- *Original and Collaborative Research* efforts 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 and collaborations with other agencies will inform the development of indicators of SC's performance, quality, and relevance including the development of methods and tools for collecting data, tracking progress and reporting against these indicators. This research will also contribute to a broad based effort to develop computational tools and visualization techniques designed to manage vast amounts of data to assist in policy and planning for the SC research programs. These tools complement the case studies described above by providing the means by which the need for a case study can be identified. Critical to the success of this effort is improvement in the quality and quantity of data describing SC research projects.

SBIR/STTR	**0**	**27**	**0**

In FY 2002, $25,000 and $1,000 were transferred to the SBIR and Small Business Technology Transfer (STTR) programs, respectively. The FY 2003 amount is the estimated requirement for the continuation of the SBIR and STTR program.

Total, Energy Research Analyses	**968**	**1,020**	**1,020**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Energy Research Analyses	
■ ERA is continued at the FY 2003 level with emphasis shifting to implementation of FY 2001-2003 research results and to facilitating Office of Science implementation of the OMB R&D Investment Criteria and the Government Performance and Results Act (GPRA) with a focus on improving performance goals and measures.	+27
SBIR/STTR	
■ Decrease due to elimination of SBIR/STTR requirement as ERA is consolidated into Science Program Direction.	-27
Total Funding Change, Energy Research Analyses	0

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Capital Equipment	100	150	150	0	--
Total, Capital Operating Expenses	100	150	150	0	--

Workforce Development for Teachers and Scientists

Program Mission

The mission of the Workforce Development for Teachers and Scientists program is to continue the Department's long-standing role of training young scientists, engineers and technicians in the scientifically and technically advanced environment of our National Laboratories. Through providing a wide variety of college undergraduates the opportunity to work side by side with many of the world's best scientists and use the most advanced scientific instruments available, this program intends to expand the nation's supply of well-trained scientists and engineers, especially in the physical sciences where the greatest demand lies. By providing K-14 teachers, mentor-intensive laboratory fellowships, this program will greatly enhance their content knowledge and skills of mathematics and science and can contribute to the national goal of a qualified teacher in every classroom.

The Workforce Development for Teachers and Scientists program supports three science, technology and workforce development subprograms: 1) Undergraduate Internships, for undergraduate students wishing to enter science, technology, engineering and mathematics (STEM), as well as with science and math teaching careers; 2) Graduate/Faculty Fellowships for STEM teachers and faculty; and 3) Pre-College Activities for middle and high school students such as the National Science Bowl. Each of the subprograms targets a different group of students and teachers to attract as broad a range of participants to the programs and to expand the pipeline of students who can enter the STEM workforce. In this fashion, the subprograms use our National Laboratories to meet the demand for a well-trained scientific and technical workforce, including those teachers that help spawn that workforce.

In response to the growing national need for highly trained teachers in their content area, the Office of Science plans to initiate a pilot program at Argonne National Laboratory (ANL) for K-14 STEM teachers, the *Laboratory Science Teacher Professional Development* activity within the Graduate/Faculty Fellowship subprogram. Through mentor-intensive experiences teachers will be provided a range of research, technical education, and training options designed to improve their classroom performance, their students' achievement, and their content knowledge in the subjects they teach. Follow-on support is critical. All teachers completing the initial laboratory experience will be provided: monetary support to help them extend what they have learned to their classes; support to enable student involvement, when appropriate, in National Laboratory research; long-term support through communication with other participant teachers and laboratory scientists; return trips to the laboratory; and support to present their experiences at professional conferences and in publications.

Significant Program Shifts

- The FY 2004 request of $6,470,000 for "Workforce Development for Teachers and Scientists" budgets Science Education in a new program. The former subprogram name changes from "Science Education" (budgeted in Science Program Direction prior to FY 2004) to "Workforce Development for Teachers and Scientists" program to more accurately reflect the program mission and scope.
- In response to the national need for science teachers who have strong content knowledge in the classes they teach, the Department is proposing a new $1,000,000 internship opportunity at ANL for K-14 teachers to help address that need. The Department of Energy National Laboratories can provide mentor-intensive professional development that compliments the efforts of states and federal agencies. The multidisciplinary, team-centered, scientific culture of the National Laboratories is an

ideal setting for teachers to make the connections between the science and technology principles they are asked to teach. More importantly, the extensive mentoring power of our laboratory scientists is an excellent vehicle to establish fruitful, lasting relationships that would allow teachers to remain connected to the scientific community once they return to the classroom. Armed with this knowledge and experience, each teacher could enter the classroom as a genuine effective representative of the exciting world of science and technology. Teacher classroom performance and student academic and career paths will help measure the long-term impact of this program.

- It is well recognized that the middle school years are the most productive time to exert an effort to attract students to science and math subjects. In FY 2002 and FY 2003 there was a small pilot for the Middle School Science Bowl and it was conducted under the auspices of the National Science Bowl. The Middle School Science Bowl activity will be expanded in FY 2004 and provide opportunities for students to develop their science and math skills in a non-classroom setting. Carefully crafted activities that are based on successful hands-on activity models will be conducted to attract their imagination, excite their interest and provide a chance for the students to experience applied science under the direction of professional scientists and engineers. Students who win in regional events will then enjoy a trip to a National Laboratory and participate in a final three day event that is designed to capture their interest and reward them for their hard work.

Funding Profile

(dollars in thousands)

	FY 2002 Comparable Appropriation	FY 2003 Request	FY 2004 Request	$ Change	% Change
Workforce Development for Teachers and Scientists					
Undergraduate Internships..........	3,165	4,075	3,768	-307	-7.5%
Graduate/Faculty Fellowships.....	568	725	1,900	+1,175	+162.1%
Pre-College Activities	727	660	802	+142	+21.5%
Subtotal, Workforce Development for Teachers and Scientists.............	4,460	5,460	6,470	+1,010	18.5%
Adjustment......................................	0	0	0	0	--
Total, Workforce Development for Teachers and Scientists..................	4,460[a]	5,460[a]	6,470	+1,010	18.5%

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 $4,460,000 in FY 2002 and $5,460,000 in FY 2003 for Science Education transferred from Science Program Direction.

Funding by Site[a]

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Albuquerque Operations Office					
National Renewable Energy Laboratory	0	150	200	+50	+33.3%
Chicago Operations Office					
Argonne National Laboratory	430	615	570	-45	-7.3%
Brookhaven National Laboratory....................	430	615	522	-93	-15.1%
Fermi National Laboratory	20	100	50	-50	-50.0%
Princeton Plasma Physics Laboratory............	125	100	150	+50	+50.0%
Chicago Operations Office	443	500	600	+100	+20.0%
Total, Chicago Operations Office.........................	1,448	1,930	1,892	-38	-2.0%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	10	0	100	+100	+100.0%
Total, Idaho Operations Office	10	0	100	+100	+100.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	505	750	600	-150	-20.0%
Stanford Linear Accelerator Center	150	150	150	0	---
Total, Oakland Operations Office........................	655	900	750	-150	-16.7%
Oak Ridge Operations Office					
Oak Ridge Institute for Science and Education...	1,377	1,250	1,292	+42	+3.4%
Thomas Jefferson National Accelerator Facility...	50	100	100	0	---
Oak Ridge Operations Office	75	75	90	+15	+20.0%
Total, Oak Ridge Operations Office	1,502	1,425	1,482	+57	+4.0%
Richland Operations Office					
Pacific Northwest National Laboratory	635	740	690	-50	-6.8%
Richland Operations Office	150	220	0	-220	-100.0%
Total, Richland Operations Office	785	960	690	-270	-28.1%
Washington Headquarters	60	95	1,356	+1,261	+1,327.4%
Total, Workforce Development for Teachers and Scientists	4,460[b]	5,460[b]	6,470	+1,010	+18.5%

[a] On December 20, 2002, the National Nuclear Security Administration (NNSA) disestablished the Albuquerque, Oakland, and Nevada Operations Offices, renamed existing area offices as site offices, established a new Nevada Site Office, and established a single NNSA Service Center to be located in Albuquerque. Other aspects of the NNSA organizational changes will be phased in and consolidation of the Service Center in Albuquerque will be completed by September 30, 2004. For budget display purposes, DOE is displaying non-NNSA budgets by site in the traditional pre-NNSA organizational format.
[b] Includes $4,460,000 in FY 2002 and $5,460,000 in FY 2003 for Science Education transferred from Science Program Direction.

Site Description

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a multi-program laboratory located on a 1,700-acre site in suburban Chicago. 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. Workforce development for scientists, technicians, engineers, and mathematics along with teachers of these disciplines are conducted at the National Laboratories through research internships and fellowships that fully immerse the participants in state-of-the-art technologies with the added benefit of a mentor-intensive relationship that helps guide them through their stay at the laboratory and fosters their continuing in STEM and science-teaching careers.

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is a multi-program laboratory located on a 5,200-acre site in Upton, New York. BNL 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. Workforce development for scientists, technicians, engineers, and mathematics along with teachers of these disciplines are conducted at the National Laboratories through research internships and fellowships that fully immerse the participants in state-of-the-art technologies with the added benefit of a mentor-intensive relationship that helps guide them through their stay at the laboratory and fosters their continuing in STEM and science-teaching careers.

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. Workforce development for scientists, technicians, engineers, and mathematics along with teachers of these disciplines are conducted at the National Laboratories through research internships and fellowships that fully immerse the participants in state-of-the-art technologies with the added benefit of a mentor-intensive relationship that helps guide them through their stay at the laboratory and fosters their continuing in STEM and science-teaching careers.

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, production and use of energy, U.S. economic competitiveness, and national security. Workforce development for scientists, technicians, engineers, and mathematics along with teachers of these disciplines are conducted at the National Laboratories through research internships and fellowships that fully immerse the participants in state-of-the-art technologies with the added benefit of a mentor-intensive relationship that helps guide them through their stay at the laboratory and fosters their continuing in STEM and science-teaching careers.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory (LBNL) is a multi-program laboratory located in Berkeley, California, on a 200-acre site adjacent to the Berkeley campus of the University of California. LBNL is dedicated to performing leading-edge research in the biological, physical, materials, chemical, energy, and computer sciences. LBNL also operates unique user facilities available to qualified investigators. Workforce development for scientists, technicians, engineers, and mathematics along with teachers of these disciplines are conducted at the National Laboratories through research internships and fellowships that fully immerse the participants in state-of-the-art technologies with the added benefit of a mentor-intensive relationship that helps guide them through their stay at the laboratory and fosters their continuing in STEM and science-teaching careers.

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. Workforce development for scientists, technicians, engineers, and mathematics along with teachers of these disciplines are conducted at the National Laboratories through research internships and fellowships that fully immerse the participants in state-of-the-art technologies with the added benefit of a mentor-intensive relationship that helps guide them through their stay at the laboratory and fosters their continuing in STEM and science-teaching careers.

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. Workforce development for scientists, technicians, engineers, and mathematics along with teachers of these disciplines are conducted at the National

Laboratories through research internships and fellowships that fully immerse the participants in state-of-the-art technologies with the added benefit of a mentor-intensive relationship that helps guide them through their stay at the laboratory and fosters their continuing in STEM and science-teaching careers.

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. PNNL conducts research in the area of environmental science and technology and carries out related national security, energy, and human health programs. Workforce development for scientists, technicians, engineers, and mathematics along with teachers of these disciplines are conducted at the National Laboratories through research internships and fellowships that fully immerse the participants in state-of-the-art technologies with the added benefit of a mentor-intensive relationship that helps guide them through their stay at the laboratory and fosters their continuing in STEM and science-teaching careers.

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. Workforce development for scientists, technicians, engineers, and mathematics along with teachers of these disciplines are conducted at the National Laboratories through research internships and fellowships that fully immerse the participants in state-of-the-art technologies with the added benefit of a mentor-intensive relationship that helps guide them through their stay at the laboratory and fosters their continuing in STEM and science-teaching careers.

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. Workforce development for scientists, technicians, engineers, and mathematics along with teachers of these disciplines are conducted at the National Laboratories through research internships and fellowships that fully immerse the participants in state-of-the-art technologies with the added benefit of a mentor-intensive relationship that helps guide them through their stay at the laboratory and fosters their continuing in STEM and science-teaching careers.

Thomas Jefferson National Accelerator Facility

Thomas Jefferson National Accelerator Facility (TJNAF) is a program-dedicated laboratory (Nuclear Physics) located on 273 acres in Newport News, Virginia. TJNAF 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. Workforce development for scientists, technicians, engineers, and mathematics along with teachers of these disciplines are conducted at the National Laboratories through research internships and fellowships that fully immerse the participants in state-of-the-art technologies with the added benefit of a mentor-intensive relationship that helps guide them through their stay at the laboratory and fosters their continuing in STEM and science-teaching careers.

Undergraduate Internships

Mission Supporting Goals and Measures

The Undergraduate Internships subprogram contains three activities:

The "Science Undergraduate Laboratory Internship" activity (formerly known as Energy Research Undergraduate Laboratory Fellowship [ERULF]) 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 internship 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, careers in science, mathematics or technology.

The "Community College Institute (CCI) of Science and Technology" provides a 10-week workforce development program through research experiences 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 that include: lectures, classroom activities, career guidance/planning, and field trips. Appointments are available during the summer. This activity has also been extended, in collaboration with the National Science Foundation (NSF), to community college students and faculty in NSF funded programs that might not otherwise have an advanced research opportunity.

"Pre-Service Teachers" (PST) is for undergraduate students who have decided on a teaching career in science, technology, engineering or mathematics. Students work with scientists or engineers on projects related to the laboratories' research programs. They also have the mentorship of a Master Teacher who is currently working in K-12 education as a teacher and is familiar with the research environment of a specific National Laboratory. Appointments are available during the summer. This activity began in collaboration with the National Science Foundation (NSF) and has been extended to all pre-service teachers.

PROGRAM ACCOMPLISHMENTS

- An innovative, interactive Internet system has been developed and implemented for all Office of Science national workforce development programs, to receive and process hundreds of student and teacher/faculty 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 Education Link.

  This system enhances communication with the participants regarding their internships, contains pre- and post-surveys that quantify student knowledge, performance and improvement, allows SC to measure program effectiveness, track students in their academic and career path, and be a hosting site for publishing student papers, abstracts and all activity guidelines.

- Through special recruitment efforts, the Science Undergraduate Laboratory Internship (formerly ERULF, now SULI) 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, 2001 and 2002 more than 500 appointments were made each year through the new application process.
- An undergraduate student journal was created and publishes full-length peer-reviewed research papers and abstracts of students in the activity. A second edition was published in 2002, with 15 full-length papers and 350 abstracts. The students who published full-length papers presented their work at a poster session at the American Association for the Advancement of Science (AAAS) national meeting in Boston. One of the students won a poster award at the AAAS meeting.
- Two Program Guidebooks were written for the student participants: 1) SULI and the Community College Initiative (CCI) guidebook provides formats and instructions for the written requirements, including scientific abstract, research paper, oral presentation, and poster; and 2) Pre-Service (PST) guidebook also includes instructions for an education module.
- The DOE Community College Institute of Science and Technology is no longer a pilot and is open to students from all community colleges. In the summer of 2002, more than 125 community college students attended a 10-week mentor-intensive scientific research experience at several DOE National Laboratories. Almost 60 percent of the participating students came from underrepresented groups in STEM disciplines; many were “non-traditional” students.

Subprogram Goals

Expand the number and diversity of participants in the Science Undergraduate Laboratory Internships, the Community College Institute (CCI) for Science and Technology, and Pre-Service Teacher (PST) programs, by establishing partnerships with other federal agencies and professional educational organizations. Also, evaluate the programs to assess the overall quality and relevance of the intern experience and track the students to determine the impact of these programs on advanced education and career goals.

Performance Indicator

Number of applicants; quality of mentorship; tracking of academic and career choices.

Annual Performance Results and Targets

FY 2002 Targets/Results	FY 2003 Targets	FY 2004 Targets
More than 1,600 applicants for the Undergraduate Internships were received (60% increase in applications). 470 students were selected for summer 2002. [Met Goal]	Increase the number and/or diversity of the applicants by 20% over FY 2002 level.	Increase the number and/or diversity of the applicants by 10%, leading to a more select group of students entering the program.
90% of students submitted acceptable abstracts. [Met Goal]	90% of approximately 500 students will submit acceptable abstracts.	90% of approximately 500 students will submit research abstracts judged as high quality by independent review.

FY 2002 Targets/Results	FY 2003 Targets	FY 2004 Targets
Develop tracking mechanisms to follow employment and career choices of participants at National laboratories and associated institutions. [Goal not met]	Complete the development of the tracking mechanisms and establish a baseline to begin following employment and career choices of participating students.	Track career choices of at least 30% of participating students, which will baseline long-term benefits of the program.
On-site review of workforce development programs at each laboratory by independent evaluators.	Evaluate quality of workforce development programs through independent evaluators.	SC Institutional Plan on-site reviews will include Workforce Development programs. Evaluate quality of workforce development programs through independent evaluators.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Science Undergraduate Laboratory Internship	2,206	3,050	2,653	-397	-13.0%
Community College Institute of Science and Technology	695	625	605	-20	-3.2%
Pre-Service Teachers	264	400	510	+110	+27.5%
Total, Undergraduate Internships	3,165	4,075	3,768	-307	-7.5%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Science Undergraduate Laboratory Internship	**2,206**	**3,050**	**2,653**

The Science Undergraduate Laboratory Internship (formerly ERULF) 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 activity 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) activity goals and outcomes are measured based on students' research papers, students' abstracts, surveys and outside evaluation. An undergraduate student journal was created that publishes selected full research papers and all abstracts of students in the activity. Students who publish in this journal present their research at the annual AAAS meeting. The National Science Foundation (NSF) began a collaboration with this activity as of FY 2001. The activity 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.

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		
Community College Institute of Science and Technology	**695**	**625**	**605**

The 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 (e.g., Lewis Stokes Alliance for Minority Participation and Advanced Technology Education program) are also participating in this activity and in FY 2002 the CCI was made available to students from all community colleges. This activity is designed to address shortages, particularly at the technician and paraprofessional levels and will help develop the workforce needed to continue building the Nation's capacity in critical areas for the next century. Since community colleges account for more than half of the entire nation's undergraduate enrollment, this is a great avenue to find and develop talented scientists and engineers. The Institute provides a ten-week mentored research internship at a DOE National Laboratory for highly motivated community college students. The paradigms of the activity 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) activity goals and outcomes are measured based on students' research papers, students' abstracts, surveys and outside evaluation. An undergraduate student journal was created that publishes selected full research papers and all abstracts of students in this activity. The National Science Foundation entered into a collaboration with this activity in FY 2001. This allows NSF's undergraduate programs to include a community college internship in their opportunities they provide to students.

Pre-Service Teachers	**264**	**400**	**510**

The Pre-Service Teachers activity is for students who are preparing for a teaching career in a STEM discipline. This effort is aimed at addressing the national need to improve content knowledge of STEM teachers prior to entering the teaching workforce. The paradigms of the activity 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 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) activity goals and outcomes are measured based on students' abstracts, education modules, surveys and outside evaluation.

Total, Undergraduate Internships	**3,165**	**4,075**	**3,768**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
■ The number of Science Undergraduate Laboratory Internship decreases by 66 students.	-397
■ The number of students in the Community College Institute of Science and Technology decreases by 4.	-20
■ The number of students participating in the Pre-Service Teachers activity will increase by 20.	+110
Total Funding Change, Undergraduate Internships	-307

Graduate/Faculty Fellowships

Mission Supporting Goals and Measures

The Graduate/Faculty Fellowships subprogram contains four activities:

In response to the national need for science teachers who have strong content knowledge, the Department is proposing a Laboratory Science Teacher Professional Development pilot fellowship at Argonne National Laboratory for K-14 teachers that will provide a mentor-intensive scientific professional development activity to improve their classroom performance and the achievement of their students.

The Faculty and Student Teams program provides research opportunities at a DOE National Laboratory to faculty and undergraduate students from colleges and universities with limited prior research capabilities and those institutions serving populations, women, and minorities underrepresented in the fields of science, engineering, technology and community college faculty, enabling a broader and lasting impact on undergraduate programs. These opportunities are also extended to faculty from NSF funded institutions.

The “Albert Einstein Distinguished Educator Fellowship” activity supports outstanding K-12 science and mathematics teachers, who provide insight, extensive knowledge, and practical experience to the Legislative and Executive branches. This activity 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 activity of distinguished educator fellowships for elementary and secondary school mathematics and science teachers.

The used “Energy Related Laboratory Equipment” (ERLE) activity was established by the United States Department of Energy (DOE) to grant available excess equipment to institutions of higher education for energy-related research.

PROGRAM ACCOMPLISHMENTS

- An innovative, interactive Internet system has been developed and implemented for all Office of Science national workforce development programs, to receive and process hundreds of student and teacher/faculty 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 Education Link.

  This system enhances communication with the participants regarding their internships, contains pre- and post-surveys that quantify student knowledge, performance and improvement, allows SC to measure program effectiveness and track students in their academic and career path, and be a hosting site for publishing student papers, abstracts and all activity guidelines.

- The Albert Einstein Distinguished Educator Fellowship Activity placed four outstanding K-12 science, math, and technology teachers in Congressional offices and two at DOE, as directed by legislation. The National Aeronautics and Space Administration, the National Science Foundation, and the National Institute of Standards and Technology contributed funds to place seven additional Einstein Fellows in those agencies.

- A pilot Faculty and Student Team (FaST) activity was hosted at three Office of Science laboratories – Argonne National Laboratory, Lawrence Berkeley National Laboratory, and Pacific Northwest National Laboratory-- in collaboration with the National Science Foundation. Faculty and students from colleges and universities with limited prior research capabilities and those institutions serving populations, women, and minorities underrepresented in the fields of science, engineering, and technology were part of a research team at a National Laboratory. Over a ten week summer visit to the laboratory the faculty were introduced to new and advanced scientific techniques that will help them prepare their students for careers in science, engineering, computer sciences and technology and for their own professional development.

Subprogram Goals

Develop grade level K-14 STEM teachers as leaders in their profession and as members of the extended scientific and technical community. Develop a tracking system to determine quality of the activity and long term impact on physical science courses being offered; inquiry based instruction in the classroom that is at grade level and matched to local standards and benchmarks; use of technology; and leadership roles in education activities.

Performance Indicator

Number of leadership roles and quality of classroom teaching techniques.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
	Develop the Laboratory Science Teacher Professional Development initiative to support professional development of K-14 STEM teachers.	Implement the Laboratory Science Teacher Professional Development initiative pilot at Argonne National Laboratory and provide follow-up support to participants. Track teachers with respect to their leadership roles and changes in their classroom teaching techniques.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Laboratory Science Teacher Professional Development	0	0	1,000	+1,000	+100.0%
Faculty and Student Teams	50	150	210	+60	+40.0%
Albert Einstein Distinguished Educator Fellowship	443	500	600	+100	+20.0%
Energy Related Laboratory Equipment	75	75	90	+15	+20.0%
Total, Graduate/Faculty Fellowships	568	725	1,900	+1,175	+162.1%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Laboratory Science Teacher Professional Development	**0**	**0**	**1,000**

The *National Commission on Mathematics and Science Teaching* and numerous other studies indicate that *professional staff development is one of the most effective ways of improving the achievement of K-14 students.* The National Laboratories can play a significant role in providing carefully designed *mentor-intensive training for science and math teachers* that will allow them to more effectively teach, *attract their students' interests to science, mathematics and technology careers*, and improve student achievement. The paradigms of the pilot "*Laboratory Science Teacher Professional Development*" activity are: 1) Teachers apply on a competitive basis and are matched with mentors working in their subject fields of instruction; 2) in the first year *about 60 teachers spend an intensive 4 to 8 weeks at a National laboratory* working under the mentorship of master teachers and laboratory mentor scientists to help build content knowledge research skills and a lasting connection with the scientific community through the research experience. *Master teachers*, who are expert K-14 teachers and adept in both scientific research experience at a National Laboratory and scientific writing, *will act as liaisons between the mentor scientists and the teacher researchers to help the teachers transfer the research experience to their classroom environments*; 3) follow-on support is considered critical. Master teachers and other teacher participants receive an $800/week stipend, travel and housing expenses. All teachers completing the initial immersion experience will be provided monetary support, which consists of approximately $3,000 to *purchase materials and scientific equipment*, to help them transfer their research experience to their classroom. Follow-on support also will include: Returning to the laboratory in the first year for *additional training sessions* of approximately 1 week long; and *long-term support* in following years through communication with other participants and laboratory scientists, more *return trips* to the National Laboratory, and support to *present their experience at teaching conferences and publications*; and 4) *outside evaluation* of program effectiveness including visits to participant teachers' schools and long term impact of the program on student achievement. Success of the pilot is based on two separate outcomes: 1) proper placement of a participant with a suitable mentor; and 2) the effect the program has on the teachers during the academic year. In FY 2004, a pilot program will be initiated at Argonne National Laboratory.

Faculty and Student Teams	**50**	**150**	**210**

Faculty and Student Teams (FaST) at Department of Energy, Office of Science Laboratories are being piloted in partnership with the National Science Foundation. Faculty from colleges and universities with limited prior research capabilities and those institutions serving populations, women, and minorities underrepresented in the fields of science, engineering, and technology are encouraged to take advantage of the FaST opportunity to prepare students for careers in science, engineering, computer sciences and technology and for their own professional development.

	FY 2002	FY 2003	FY 2004
	(dollars in thousands)		
Albert Einstein Distinguished Educator Fellowship...	**443**	**500**	**600**

The Albert Einstein Fellowship Awards for outstanding K-12 science, mathematics, and technology teachers continues to be a strong pillar of the program for bringing real classroom and education expertise to our education and outreach activities. Albert Einstein Fellows bring to Congress, DOE and other Federal agencies extensive knowledge and experience of classroom teachers. They provide practical insights and "real world" perspectives to policy makers and program managers.

	FY 2002	FY 2003	FY 2004
Energy Related Laboratory Equipment	**75**	**75**	**90**

The used "Energy Related Laboratory Equipment" (ERLE) grant activity was established by the United States Department of Energy (DOE) to grant available excess equipment to institutions of higher education for energy-related research.

	FY 2002	FY 2003	FY 2004
Total, Graduate/Faculty Fellowships	**568**	**725**	**1,900**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
■ Initiate the Laboratory Science Teacher Professional Development pilot at Argonne National Laboratory for approximately 60 science, technology, engineering and mathematics (STEM) teachers in grades K-14.	+1,000
■ This allows an increase of 3 Faculty and Student Teams to participate in a 10 week mentored research experience at a DOE National Laboratory.....................................	+60
■ Increase the number of Fellows, their stipends and administrative expenses for the Albert Einstein Distinguished Educator Fellowship...	+100
■ Increase the used Energy Related Laboratory Equipment activity to upgrade and maintain the web-based on-line system.	+15
Total Funding Change, Graduate/Faculty Fellowships...	+1,175

Pre-College Activities

Mission Supporting Goals and Measures

The Pre-College Activities subprogram contains two activities:

The "National Science Bowl®" activity is a highly visible educational event and academic competition among teams of high school students who attend science and technology seminars and compete in a verbal forum to solve technical problems and answer questions in all branches of science and math. This activity is a highly publicized academic event among high school students who answer questions on scientific topics in astronomy, biology, chemistry, mathematics, physics, earth, and general science. Since its inception, more than 80,000 high school students have participated in regional tournaments leading up to the national finals.

The Middle School Science Bowl will attract students at the most critical stage of their academic development. The emphasis at this grade level will be on discovery and hands-on activities such as designing, building and racing model solar cars.

PROGRAM ACCOMPLISHMENTS

- Three additional regional competitions were held in conjunction with DOE's National Science Bowl®. More than 12,000 high school students participated in the 64 regional science bowl tournaments.
- A pilot Middle School Science Bowl was added in FY 2002, bringing eight teams to Washington DC for the National event. The event had two main activities: 1) a science and mathematics academic question and answer forum; and 2) a hands-on activity where each team designed, built and raced a scale-model solar car.
- Saturday morning science seminars were added to the National Science Bowl weekend, introducing students to many contemporary issues and findings in scientific research. A Nobel laureate from the National Institute of Standards and Technology (NIST) also spoke to all the students on Saturday morning.
- 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.

Subprogram Goals

Broaden the educational impact and outreach of the "Science Bowl" competition by increasing the number of scientific seminars; improve and expand the middle school component of the science bowl, and increase the number of participating schools in both the National Science Bowl and the Middle School Science Bowl.

Performance Indicator

Number of participants, quality of science seminars and other educational enrichment activities.

Annual Performance Results and Targets

FY 2002 Targets/Results	FY 2003 Targets	FY 2004 Targets
Pilot a Middle School Science Bowl; Nobel Laureate speaker at National Science Bowl.	Increase the number of students participating at regional events; and increase number of scientists giving seminars at Science Bowl.	Increase the number of students participating at regional events; and increase number of scientists giving seminars at Science Bowl.
Extend the science education of the Science Bowl beyond the current academic, question and answer event, to a broader experience by including a hands-on engineering event where students build and compete in a model solar car competition.	Enhance the hands-on elements of Science Bowl by having students build and compete in a model fuel cell car competition.	Collaborate with industry partner to increase the number of students and regional events for the model fuel cell car competitions.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
National Science Bowl	727	660	702	+42	+6.4%
Middle School Science Bowl	0	0	100	+100	+100.0%
Total, Pre-College Activities	727	660	802	+142	+21.5%

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
National Science Bowl	**727**	**660**	**702**

SC will manage and support the National Science Bowl® for high school students from across the country for DOE. Since its inception, more than 80,000 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 mathematics 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. An entire day of Saturday seminars in the latest scientific topics and the hydrogen fuel cell challenge has 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.

	FY 2002	FY 2003	FY 2004
Middle School Science Bowl	**0**	**0**	**100**

It is well recognized that the middle school years are the most productive time to exert an effort to attract students to science and math subjects. *There are two competitions at the Middle School Science Bowl –*

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004

an academic mathematics and science competition and a model solar car competition. The academic competition is a fast-paced question and answer contest where students answer questions about earth science, life science, physical science, mathematics, and general science. The model solar car competition challenges students to design, build, and race model solar cars. Students who win in regional events will then enjoy a trip to a National Laboratory and participate in a final three day event that will be designed to capture their interest and reward them for their hard work.

	FY 2002	FY 2003	FY 2004
Total, Pre-College Activities	**727**	**660**	**802**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
▪ This is to increase the number of National Science Bowl teams and to also provide a whole day of scientific seminars and workshops for the students.	+42
▪ Initiate the Middle School Science Bowl activity, which will include an academic mathematics and science competition and a model solar car competition	+100
Total Funding Change, Pre-College Activities	+142